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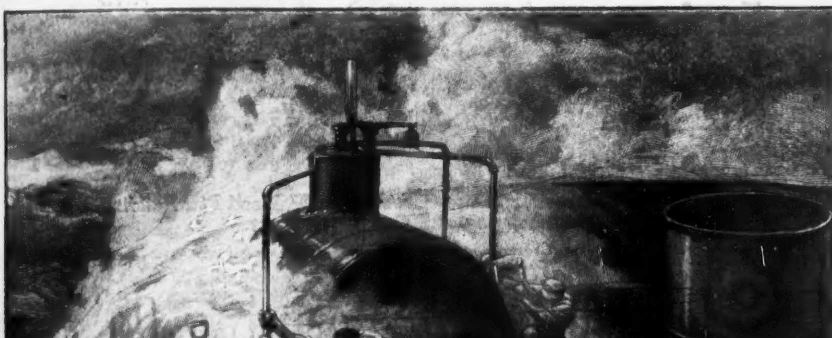
Compressed Air

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. V. NEW YORK, NOVEMBER, 1900. No. 9



THE USEFULNESS OF COMPRESSED AIR UNDER DIFFICULTIES. VIEW OF THE WORK OF BUILDING THE FOUNDATION FOR A LIGHTHOUSE AT SMITH POINT, AT THE HEAD OF THE POTOMAC RIVER, CHESAPEAKE BAY. THE WORKMEN ARE SEEN CLINGING TO THE COMPRESSED AIR PIPES DURING A STORM.

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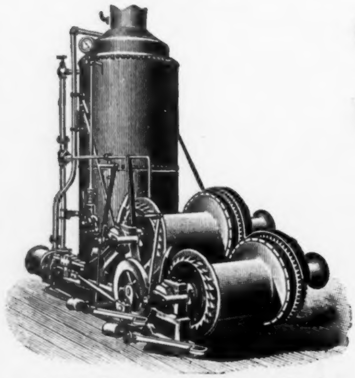

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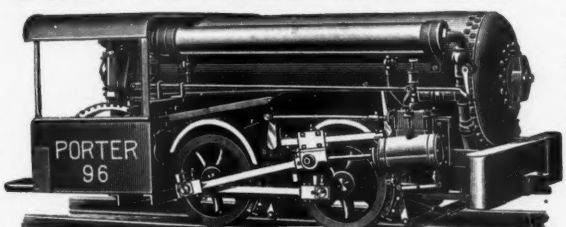

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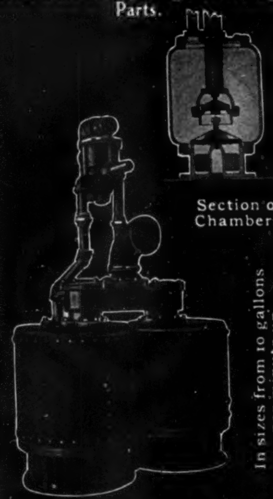

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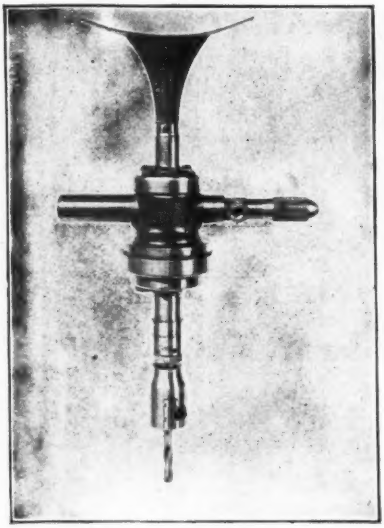

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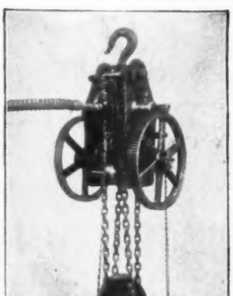

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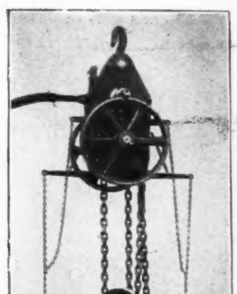

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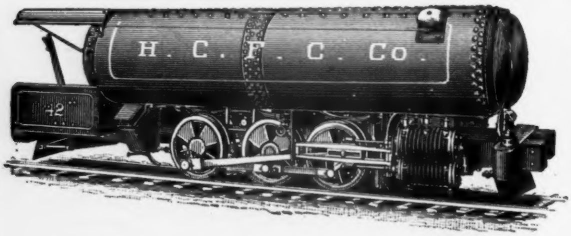

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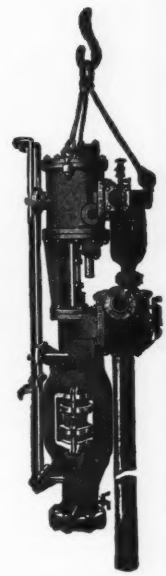

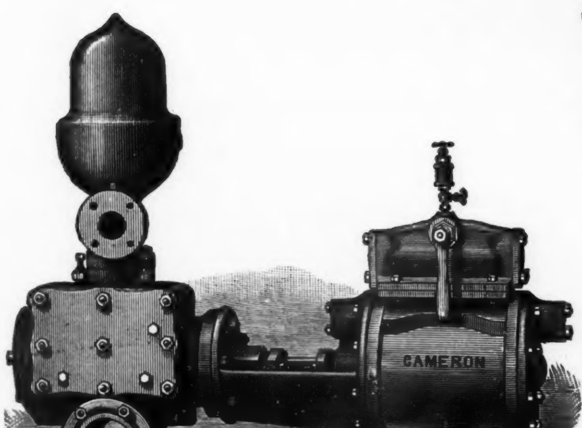

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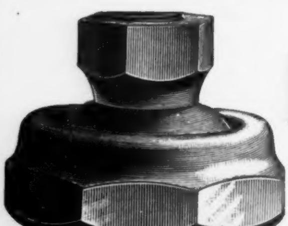

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Continuing the important subject of explosions in compressed air passages, which was alluded to in our last issue, we are convinced that in some cases the cause of the explosion may be attributed to the fact that one or more of the discharge valves fails to close at the end of the stroke of the air compressor, and thus a portion of the hot compressed air from the receiver is let back into the cylinder. The result of this is that when the piston returns for another stroke of compression it acts against a cylinder full of hot compressed air, both temperature and pressure being higher than normal. It is quite possible that the discharge valve which has admitted this hot air may close before the return stroke of the piston. Hence we have bottled up in the cylinder an unnatural condition of things, which will result in a temperature higher than normal as soon as this air has been compressed to receiver pressure. If we admit air into the cylinder of the compressor at a temperature of 60 degrees F., and at normal atmospheric pressure, this temperature will reach about 415 degrees F. when the gauge registers 75 lbs., thus showing an increase of temperature of 355 degrees. Now, it is a well known fact that all good air compressors have cooling devices, such as water jackets, for the purpose of keeping down this temperature during compression, but it is also quite as well known among those who had had experience in this matter that in large cylinders these water jackets have very little cooling effect. Hence in air compressor cylinders as usually made we may expect approximately the large increase of temperature hereinbefore mentioned. To illustrate this still further, when a volume of air is compressed without cooling to 21 atmospheres (294 lbs. gauge pressure) it will occupy a volume a little more than one-tenth. The total increase of temperature, assuming that we start at an initial temperature of zero, is about 650 degrees; but if we start with an initial temperature of 60 degrees, the total increase is about 800 degrees, and if we start with 100 degrees initial temperature the increase is 900 degrees. When free air is admitted to a compressor cold, the relative increase of temperature during compression is less than when the air is admitted hot. This being the case, we see how important it is to admit air to the cylinders of an air compressor at low temperature, for a high initial temperature means a greater increase of temperature throughout the stroke; and only a slight defect in a discharge valve might result in the destruction of the machine, because of the admission of a small quantity of hot compressed air, thus raising the temperature in the cylinder beyond the flashing point of the oil. We are inclined to think that a leaky discharge valve is responsible for many serious accidents in air compressor ser-

vice, and this points to the importance of the discharge valve as a feature of the air compressor. It should be designed in such a way as to at least minimize the liability of sticking or leaking. Even with the best form of discharge valve trouble may arise because of the use of bad oil or of too much good oil. Engineers are apt to suppose that an air cylinder of a compressor requires oil just as a steam cylinder does. This is a mistake. Too much oil results in obstruction of the parts and passages, and through the heat a carbon deposit is formed, which causes sticking. This carbon deposit is nothing more than what will result if oil is placed on a hot shovel and allowed to evaporate, except that in the cylinder of an air compressor this evaporation process is going on all the while, and in the course of time a hard, black deposit is formed which interferes with the proper working of the parts. Some engineers find out that this deposit is easily cut away by kerosene oil, and in their anxiety to take the quickest way to remedy the difficulty they throw kerosene oil into the inlet valve—a course which sometimes proves to be the surest way out of all earthly difficulties. Kerosene oil has a flashing point of 120 degress F., and it is not difficult to understand what the cause of the explosion is under such circumstances.

Air compressors should be provided with discharge valves that are easily accessible and engineers in charge of the plants should clean out all discharge valves and passages at least once a week. Care should also be taken to use a good grade of non-carbonizing oil of a high flashing point, and to use very little of it; one drop every five minutes is enough. Care should also be taken to see that the pipes and passages leading from the discharge valves to the receiver are large and accessible. The receiver itself should be provided with a man-hole and be cleaned out at regular intervals. If, as we have found in some cases, the trouble continues to exist, except that it is now tranferred to the pipe line, our next remedy should be to place an after cooler at the receiver, and in this way reduce the temperature of the air to normal condition before it is started on its journey. This is invariably done in pneumatic service, such as switching and signaling work, where it is important to maintain uniform conditions in the air pipe and where dry air is essential. This after cooler is nothing but a surface condenser, which reduces the temperature of the compressed air, causing it to deposit its moisture. There can be no trouble from explosions in a pipe line equipped in this way, and where these lines are long, and where the pipe is laid under ground, the after cooler serves also to prevent much trouble from expansion and contraction. Air pipes laid on the surface in an irregular way over the ground will usually adjust themselves to changes of temperature, but if boxed up or buried the joints are apt to give trouble, unless allowance is made for expansion and contraction, and this is minimized where the compressed air, after leaving the receiver, is brought down to normal conditions.

Percussive Tools.

An Inertia Valve Percussive Tool.

Paper Read Before the Engineers' Society of Western Pennsylvania.

By Chester B. Albree.

In the last few years the use of compressed air as a motive power for machinery has wonderfully increased, especially for portable tools. This is mainly due to the advantageous qualities of compressed air over steam, the principal of which are:

First. Stability, or in other words, non-condensation, permitting it to be stored indefinitely, or to be transported long distances without loss of pressure, other than that due to leakage and friction of the conduit.

Second. Low temperature at which it can be used in hand tools. Such tools could be run by steam, but they would become so hot that a man could not hold them in the naked hand.

Third. The exhaust consists of fresh cool air, adding to the ventilation and comfort of the workroom or mine, whereas the exhaust from steam motors has to be disposed of outside, and is a nuisance, and with hydraulic systems, the waste water must be carried away in pipes.

Fourth. It can be used at any pressure and is easily produced, and its expansive qualities, while not on a par with steam, owing to the absence of heat, yet can be utilized with good results, a feature entirely absent in hydraulic systems.

Against these advantages are opposed some few disadvantages, such as the losses of power in the compression of air, due to the absorption of energy in the generation of heat, and the subsequent loss of pressure in the compressed air, as it cools down to the temperature of the surrounding atmosphere. The losses of the steam end of the compressor are similar to those of any steam engine, and are well known to all of you.

The absorption of heat from surroundrounding media, caused by the sudden expansion of compressed air, often to such an extent as to freeze any moisture in the air or immediate neighborhood, will often prevent the use of high pressure air expansively unless the air be reheated. This reheating of compressed air can be done at very small fuel cost for the benefits attained, and is used in many places.

These points, however, are well understood and compressed air is used intelligently.

With these few reminders of the qualities of compressed air, the subject of its application to percussive tools comes up, which can be better understood by prefacing with an outline of the development of percussive engines of different types, followed by a description of the inertia valve type which is the subject of this paper, and a discussion of some of the theoretical and engineering features involved in its design.

Percussive force, as regards the actual work done upon the object struck, is applied in two ways:

First. Directly, when the tool itself is propelled through space and strikes the object, when practically all of the energy of the moving mass is expended on the object struck. The commonest examples are the hand hammer, sledge, steam hammers, rock drills, mining stamps and others of similar character.

Second. Indirectly, when the moving mass strikes an interposed tool, through which the energy is transferred to the object.

In this case a portion of the energy is consumed in overcoming the inertia of the interposed tool; the remainder only performing useful work on the object. The energy thus consumed in overcoming the inertia of the interposed tool, supposing the energy of percussive force to be constant, varies, by well known laws, according to the weight or mass of the interposed body. The mathematical discussion of inertia is out of place in this paper, but those interested in the subject can find full discussion of it in Weisbach's, Rankine's and other works on applied mechanics.

Examples of this second type of application of percussive force are the mason striking his stationary chisel, the quarryman's drill struck by the sledge, and the chisel struck by the piston of a pneumatic hammer.

After hand hammers, which have been used from time immemorial, perhaps the lifting of a weight and subsequent dropping it, was the first step in advance, and one which is still in daily use in drilling oil wells and driving piles.

Trip hammers of crude form were in use as early as 1600, and before them, spring catapults were used to throw great stones against castle walls. In a manner these may be classed as hammers of the first type, as the projectile certainly struck a blow, as do those of our great modern rifles, with a little more force.

Nasmyth's steam hammer, invented in the early forties, was a great step forward, and undoubtedly led to the invention of the rock drill, although as far back as 1683 a drill of the oil well type

was used for rock, but only vertical holes could be drilled.

In 1844 one Brunton suggested compressed air in a cylinder as a convenient means of working a hammer to hit a drill, and in 1859 Nasmyth, who was a wonderful engineer, at a meeting of the British Association for the Advancement of Science, suggested that the loss of energy in overcoming the inertia of an interposed tool could be overcome by lancing or projecting the tool itself against the work, and exhibited a sketch of an ingenious machine having a piston with a tool attached to the piston rod, working in a cylinder, closed at the lower end and open at the top, so arranged that when the piston was mechanically pulled to the back of the cylinder, a vacuum would be created below it, and on releasing the piston the atmospheric pressure would drive it down with a constantly increasing velocity. This device, he pointed out, could be used to drill holes at any angle, as it was independent of gravity for its power.

October 15, 1851, Cave, a Frenchman, patented a machine for rock drilling, run by compressed air, in which the valve was actuated by hand, and the drill rotated by hand. It was a double-acting engine and was successfully used, and was the pioneer rock drill in Europe.

Couch, an American, patented a rock drill in 1849 in which both the valve motion and the rotation of the drill were automatically performed by the piston in its motion, and while it was a cumbersome machine, requiring cranes to handle it, it was in its essential features the rock drill of to-day.

Since that time there have been wonderful improvements in detail, and numberless devices made for regulating and controlling the different parts, yet to America belongs the credit of the real development of the rock drill.

There are three methods of automatically controlling the admission of motive fluid in rock drills and other percussive engines.

First. The tappet valve type, in which projections attached to the reciprocating part, strike triggers or other devices which in turn move the valve.

There are several objections to this type. The clearances are necessarily large, the liability to breakage is great, due to the intricacy and multiplicity of parts; the small variation of stroke permittable and the fact that the valve must be moved before the piston has completed its stroke.

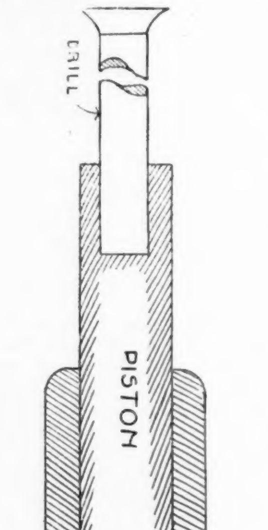


FIG. 1.

This is a good feature on the back stroke, as it permits of forming a sure cushion preventing piston hitting back cylinder head, but on the front stroke it

is bad, as it allows initial pressure air to bear against and partially check the velocity of the piston, hence weakening the possible blow.

Owing to the skill and care with which machines of this type are constructed, most excellent results have been and are now being accomplished with them, and such well-known manufacturers as the Ingersoll-Sergeant and the Rand Drill Companies, continue to sell them in large quantities.

Second. The fluid moved valve type, wherein the piston itself, at certain parts of its travel, admits a supply of motive fluid to move the valve or to move a supplementary piston which in turn moves the valve.

Such machines, if well made, are not liable to get out of order, but the stroke is subject to limitation within narrow range of length, and air is admitted before end of out stroke, as was described of the tappet valve type.

In neither type has there been much attempt to use the air expansively, as the decreased velocity due to decreasing pressure, and the additional mechanical complications, did not seem to warrant it.

The Optimus Drill, of English make, is an exception. It belongs to the fluid-moved valve type, using the motive fluid compound. The initial fluid driving the piston outward, is used expansively to effect the return stroke. It is much in use abroad, but has not met with much favor here.

Third. The so-called valveless type, in which the moving piston acts as its own valve, as in its stroke, it alternately opens and closes certain ports, so that the fluid acts on each end of the piston in turn.

The progenitor of this type was invented by John Darlington, May 13th, 1873, in England, and a great many were used, though now superseded by the modern drills of the first and second types described.

In this machine, the motive fluid acts constantly on the smaller area of the piston. When the piston is at the outer end of its stroke, the space in the rear is open to the atmosphere and the constant pressure on front area forces the piston back. In its motion, it closes the exhaust port and a back cushion is started in the rear. At a certain distance before the motion of piston is entirely checked by the cushion, a by-pass leading from front to rear end of cylinder, is opened; this by-pass being a little longer than the main body of piston. Fluid rushes through this passage to the space in rear of piston, pressing on large diameter of same with initial pressure, drives piston forward against the pressure on small diameter, with a force due to the excess of area, under the same pressure per square inch. Very early in the down stroke, the by-pass is closed again by body of piston, and further force is derived only from the expansion of the body of high pressure fluid, locked in the rear of piston.

Against this decreasing pressure of expansion is opposed the constant pressure on the small front area, so that the net forward force is constantly decreasing, although sufficient, combined with the momentum already acquired, to propel piston its entire stroke with considerable velocity, utilized in effective work on the object struck by the tool. When nearly at end of out stroke, the exhaust in rear is again opened, so that further travel is entirely due to the acquired momentum. As soon as the blow is struck, the piston is stopped, and immediately is pushed back by pressure on front area and the operation repeats.

The conception is unique and beautiful, the drawback being the loss of velocity on the out stroke, as described.

The action of this tool has been explained in detail, as it was in the endeavor to overcome this defect that experiments and study were made of the problem.

In Darlington's drill, the initial pressure was used for the back stroke, and the expansive force used for the out stroke. April 13th, 1880, Wm. L. Neill took out a U. S. patent for a valveless rock drill, reversing this action, so that the effective out stroke was due to initial pressure, and the return stroke to expansion. This device never was used practically, as far as can be ascertained, probably due to the fact that a cushion was formed in front of the piston, when the exhaust was closed, increasing in force as the piston progressed, and decreasing the velocity thereof.

Having thus examined the three principal types of valve motion in ordinary use, we come to the development of the Pneumatic Hammer, which consists essentially of a small portable cylinder in

which a piston reciprocates very rapidly, striking a great number of blows per minute on the end of a tool inserted in the end of the cylinder.

It belongs to the second class of percussive tools, having a tool interposed between the hammer and the work.

McCoy may be said to be fairly entitled to the credit of the first application of such tools to heavy work, such as chipping metals, caulking boilers, cutting stone, &c., that had been done previously by hand and hammer. He exhibited his device before the Franklin Institute, which awarded him a medal for a new and meritorious invention of real utility.

He was not, however, the originator of the broad idea, as long before he perfected the tool for heavy work it had been used as a dental plugger, a device working compressed air in a cylinder so that a piston struck the end of a tamping tool, used to insert gold into the cavities of teeth.

There were several patents taken out for such tools and successful results attained in the 70's.

similar tool, the Kotten, is made for use in carving stone and marble, die sinking and other delicate work, and has a very short stroke, about ¼" to ½", running as high as 10,000 or more strokes per minute.

For heavy chipping, riveting and other work, the blow of a valveless tool is not heavy enough to do the work well, and tools with a controlling valve are used, allowing of much longer stroke, and higher velocities of piston travel.

Of the fluid-moved valve type, the Boyer hammer, made by the Chicago Pneumatic Tool Co., and the Little Giant hammer, made by the Standard Pneumatic Tool Co., are the best known. In these a small valve, located in a chamber in the rear of the piston, traveling parallel or right angles to the axis of the piston, is actuated by air pressing on differential areas, moving it alternately to and fro, opening and closing ports controlling the admission and exhaust to the cylinder. Suitably placed small ports are closed and opened by the piston in its travel, that permit air to act on and move this valve.

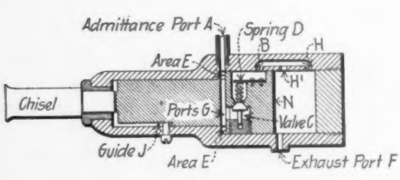


FIG. 2.

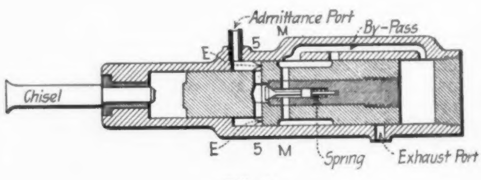


FIG. 3.

The pneumatic hammers followed in a general way, the valve motions used in rock drills, with modifications adapted to smaller and more portable tools. The valveless, as also tappet and fluid moved valve, types are used. Of the former, the Q. & C. tools are quite well known. For work within their range they are admirable, owing to their simplicity of design, small size and great rapidity of short stroke blows. For light chipping, caulking and other similar work they can hardly be excelled. A somewhat

Excellent work is accomplished by these tools, and a skilled workman can do from four to six times as much as can be done by hand tools alone. They are in use in nearly all the progressive machine, boiler, bridge and ship works in this country, and in a great many abroad.

In driving rivets greater force is required than in chipping. This can be attained in a pneumatic hammer in two ways: By larger mass in the piston, or by greater velocity.

The force of the blow varies directly as the mass or weight; and as the square of the velocity; hence a tool can be designed with a heavy piston and short stroke with high pressure, or the same result attained by larger cylinder diameter with lower pressure, but the better, and generally adopted method; is to increase the length of stroke, keeping the diameter small. This would follow theoretically as a result of the law given. There is again a practical reason why the diameter should be kept small, because the reaction would otherwise be too great. Since action and re-action are equal and in opposite directions, the total force used to propel the piston out, presses equally against the back cylinder head, and a man can withstand but a limited amount of such pressure when holding the tool, thus limiting the diameter to such size as has been found practicable.

To meet the demand for a long stroke tool, the Chicago Pneumatic Tool Co. have put on the market the "Long Stroke Boyer Hammer" having a piston about 1½-in. diameter, with 9-in. stroke, striking a very hard blow, due to the contiued application of a constant force through the long stroke, constantly accelerating the piston velocity. The valve is moved by tappets and at pressures of about 100 lbs. per square inch. ⅞-in. rivets can be set down much quicker and about as tight as by hand, but the rivets do not fill the holes as well as those driven by compression riveters, driven by air, steam or hydraulic pressure, nor nearly so quickly. For the erection of structural work, or for any field riveting, it fills a long felt want, doing the work sufficiently well.

With this perhaps rather long examination of what has been accomplished in percussive tools, and study of the underlying principles, the subject of this paper, "An Inertia Valve Percussive Tool," will be discussed.

Recalling the Darlington Valveless Rock Drill and referring to the drawing (Fig. 1), we notice that when the rear edge F of the piston passes exhaust port D on the back stroke, that a cushion is at once started in the rear, increasing in pressure as the piston travels back. When the front edge A of the piston passes and opens the entrance B of the by-pass B-C, initial pressure air flows through admittance port M, cylinder cavity and the by-pass to the rear of the piston, immediately checking any further movement and forcing the piston out by reason of the greater area of surface F over surface A. In such forward movement the edge A again closes the port B of by-pass, cutting off the supply of further initial pressure air to the rear, so that any additional pressure or force upon rear area of the piston must be derived from the expansive action of the air locked in behind it, which, you will notice, is opposed by the initial pressure air bearing on surface A, which is constant at all points of stroke, either forward or back.

It seemed, on study of this device, that if some way could be found to allow air of initial pressure to follow up the piston during its entire downward stroke, that much greater piston velocity would be secured.

To accomplish this result it was obvious that an automatically moved valve of some sort must control the flow of air in such a way as to prevent any access to the rear during the back stroke, and to permit such access during the forward stroke.

The first solution that appeared was the use of a type of poppet valve, with a spring bearing upon it, so that when there was no pressure on one side, the valve would close under unbalanced pressure, but when the pressure was alike on each side, the spring would force it open.

To clearly understand it, referring to the print A is a port admitting air continually against area E. G is a port leading from this area E to the valve chamber shown.

C is a valve with spring D bearing against the side of it that is away from the constant supply of initial pressure in port G, arranged so that pressure against it from port G will close it against pressure of spring, when no pressure exists back of it.

B is a by-pass having two outlets communicating with cylinder h & h^3. F is an exhaust port, adapted to be closed and opened by the rear edge of the piston. J is a guide to prevent piston from turning, as the device as shown required that the valve cavity should not come in contact with the exhaust port F.

In action, air enters through A, pressing against small area E closes valve G and forces the piston back, the space in

the rear of piston and in the by-pass and valve cavity having exhausted through port F.

When the piston travels so that the edge E passes port B, air at high pressure goes through by-pass to rear, and at the same time through the port h into the valve cavity, thus equalizing the pressure on the sides of valve C, which opens under the pressure of the spring D, permitting free passage of the air through port E, and the valve cavity port h and by-pass to the rear, forcing the piston out, owing to the excess area.

As it travels out, this passage, either through B or h is continually open, so that a continuous current of air flows through the valve at initial pressure until the exhaust port is opened at F, reducing the pressure in the rear when the valve again closes, and the action is repeated as described.

This seemed very nice on paper and worked fair to middling badly. When the spring C was exactly right in intensity for a given air pressure, it worked nicely, but any variation of pressure interfered with good results. Again the rush of air though the valve had a strong tendency to close it, requiring a superfine adjustment of the intensity of the spring.

For static pressures the idea was all right, but for dynamic pressures, if one could so call air under pressure in motion, it was not all that could have been desired.

In the line of simplicity and experiment, a rearrangement of the parts was made, as shown in drawing.

The poppet valve was placed in the axis of the piston, which did not then require guides to keep it from turning and the construction was simpler. Results somewhat better than in the first machine were attained, but it was discovered that the inertia of the poppet valve interfered with the contemplated action of the device.

This movement of the valve by inertia suggested the use of a form of slide valve that should be controlled entirely by inertia, opening and closing suitable ports in its travel to accomplish the desired ends.

A tool as shown in the drawing was designed, having an axial hole in the centre, within which a small tube could move freely within fixed limits.

A constant supply of air is admitted at 4 against the small area of piston. Ports 5-5 lead from a point adjacent

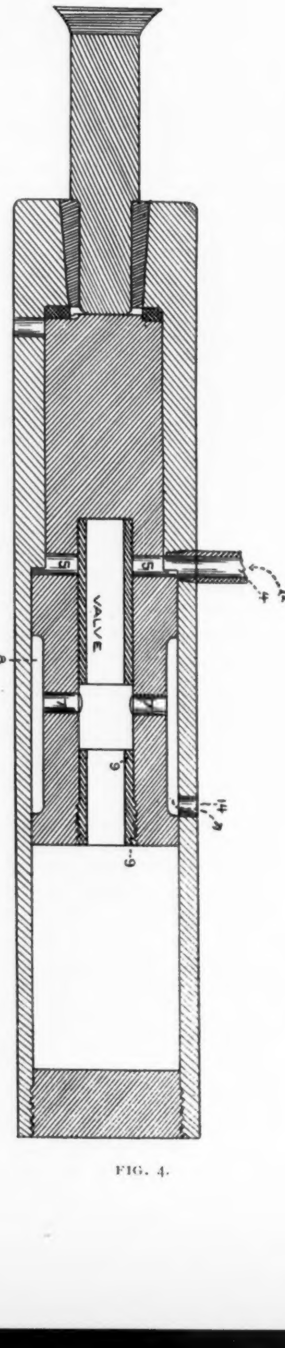


FIG. 4.

to this small area into valve chamber, which in turn opens to the rear end of piston.

An exhaust port, 14, leads through the cylinder and a groove around exterior of piston communicates by a port 7 to the valve chamber.

In starting, the tubular valve is at the outer end of chamber, thus closing ports 5-5 and leaving ports 7-7 open.

Owing to the constant pressure on the small area, and the exhaustion of pressure in rear of piston, it travels back, and the rear edge closes exhaust port 14, which, however, registers at the same instant with annular groove on piston, establishing a new means of exhaust through the valve chamber, ports 7-7 and annular groove 8 to port 14. This passage remains open until the groove 8 passes exhaust port 14 and the piston cuts off further exhaust. A cushion then commences which tends to check the velocity attained by the piston, but not that of the valve carried thereby and traveling with equal velocity. Being free to move, the valve slides back until it meets stop 9.

In this position the interior exhaust ports 7-7 are closed, and the admittance ports 5-5 are opened, and initial pressure air flows through the valve to the space in rear, driving piston out by reason of the excess area.

The valve remains in this back position, allowing air to flow through it until the piston has struck its blow, when the valve slides, by reason of its inertia, to its outer position, and the action repeats as described.

It will be noticed that full pressure is exerted until after the piston has struck, and also that the valve will shift at any point during the out stroke if the piston is stopped, provided that exhaust can occur. The possible limit of practicable variation of stroke is thus only limited by the distance found necessary to use for a rear cushion to prevent piston from ever striking the back cylinder head.

This varies from ¼ to 1-3 of the stroke length, thus permitting a wonderful variability of stroke.

The tool, as described, worked very well at times, but it was discovered that the valve had a strong tendency to bounce back, especially on the front stroke. This unlooked for movement of the valve had very disastrous effects, as may be imagined, causing the action to be extremely erratic.

To obviate this trouble, brakes were applied to the valve to prevent its sliding so easily. The machine ran well when it got a good start, but the valve was liable to stick at the wrong end of the chamber, and there was great difficulty in starting again until the piston had been jarred by hand so as to bring the valve where it should have been.

Other expedients, such as the use of rubber, lead, wood and other buffers, supposed to be inelastic, were tried in the endeavor to stop the bounce, with but little success, as anything soft enough to prevent bouncing was soon hammered out of all shape, the pieces clogging up the valve chamber.

All sorts of shifts, profoundly wise and exceedingly foolish, met the same fate, until we were almost disheartened and disgusted with the perversity of things inanimate.

In pondering over the failure, the idea of counter-balancing the rebound of the valve by a smaller mass, colliding it with it at the instant rebound commenced, arose.

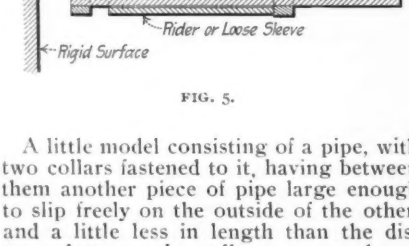


FIG. 5.

A little model consisting of a pipe, with two collars fastened to it, having between them another piece of pipe large enough to slip freely on the outside of the other, and a little less in length than the distance between the collars, was made.

On holding this device about three or four feet above a block of steel, with the outer tube or "Rider" as it was named bearing against the upper collar, it was dropped vertically. The lower end of the inner tube struck first and started to rebound, but the rider, traveling at the velocity due to the fall, slipped over the main tube until it struck the lower collar, fast on inner tube, thereby checking the upward velocity of the rebounding inner tube, so that the combination

practically did not rise perceptibly from the steel block, landing almost as dead as a chunk of putty.

It seemed as if this principle could be applied to the valve, so as to overcome its rebound, and at the same time give the freedom of motion necessary to good action.

A modification of the valve was made with a rider attachment, which, when tried, caused the tool to work with the regularity of clock work.

In designing the valve and rider, a study was made of the coefficients of rebound of various materials, and it was found that a great deal of difference in results and theory existed among the acknowledged authorities on applied mechanics, authors of distinction, such as Rankine, Weisbach and others giving tables with wide variations for similar materials.

If a body suspended from a small cord from a fixed point be made to oscillate like a pendulum, it will acquire a velocity, at its lowest point, proportional to the chord of the arc through which it has swung, and if the arcs are not very long, the times of descent will be equal for different length arcs; hence, if the suspended body strike a stationary body when at its lowest point, and the angular distance through which it rebounds be noted, the ratio of the original to the return velocity can be determined.

It was found that for steel striking steel, it was as 100 to 60, and for steel striking vulcanized rubber, backed by steel, about 100 to 37. The fibre was used as it stands the pounding of the valve without itself disintegrating, or upsetting end of valve.

Knowing, then, the modulus of recoil, we can figure the velocity a body will ac-

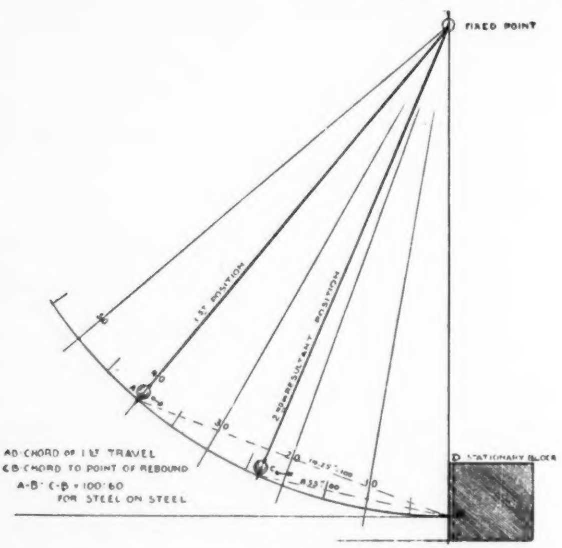


FIG. 6.

In order to be sure, recourse was had to experiment with different materials, to determine what proportionate weights the valve and rider should have to each other.

It has been demonstrated by mathematicians that the modulus of elasticity of rebound is equal to the ratio of the relative bodies after and before impact.

quire at the instant after collision on the rebound, if we know the velocity with which it struck.

If, in addition, we know the weight of the striking mass we can find the energy or momentum at that instant, and have only to make the weight of rider such that its momentum, due to the initial velocity, shall be equal to that of the

valve rebounding, to practically eliminate the return movement of the valve. When two perfectly elastic bodies of equal weight meet, each rebounds with substantially the same velocity with which they met, but with imperfectly elastic bodies, of unequal masses and velocities, the rebound depends on which has the greater weight and velocity, and on the moduli of recoil, hence we can approximately calculate the weight of rider so that the valve will stop short, and any rebound will occur in the rider only. This rebound can be made so little that it does not influence the valve itself, and the desired result is attained.

In making these investigations, certain interesting points came up that are worthy of further study to fully understand the reasons for them.

The recoil certainly depends upon the elasticity of the colliding bodies, yet the ratios found by experiment seem to bear no recognizable relation to the established coefficients of elasticity, given in text-books on the strength of materials. Evidently the amount of energy in the moving masses and the area of contact influence the result. If the striking area is small, the entire energy, converted into work, is exerted on a small unit of surface, causing a strain per unit area greater than the materials would stand. In this case the limit of elasticity, as ordinarily understood, might be exceeded when the work would be expended on tearing or crushing the material, instead of causing rebound.

On the other hand, if a body of equal weight and velocity to the one described, but having a much larger striking area, were to collide, it might easily be conceived that the strain per unit of striking area would be less than the limit of elasticity of the materials, and that practically most of such energy would be consumed in bending or squeezing the materials, which would spring back to their original position, and in so doing force the colliding body back into space with a velocity dependent upon the strain produced and the coefficients of elasticity of the bodies.

To elucidate the truth of this hypothesis would require a great deal of careful experiment and research, and would be suitable work for some mechanical laboratory connected with a technical school. Accurate information on the subject would be of great value. It might originate a new method of testing materials, although somewhat analogous to impact testing that is now in vogue, although the results in the latter system are derived from measurements of bends made transversely in the specimen struck. By this method, such results would probably be derived from a comparison with the velocities of rebound from standard substances, of bodies of given form and with given velocity.

The latest model of a direct acting chipping tool is shown in the accompanying sketch. You will note that the valve will move at any point of the stroke, if the velocity of piston be checked, and that within the limits for cushion described earlier in this paper, the stroke is variable.

While this variability of stroke is not so essential in a chipping hammer, or any tool of the second class of percussion where an interposed tool receives the blow, yet for machines of the first class, such as rock drills, steam hammers, gold mine stamps, &c., such variability is desirable and essential to attain the best results.

In this hammer the exhaust takes place at very nearly the initial pressure, hence a great deal of energy contained in the compressed air is wasted, although the piston velocity on the down stroke is great, giving a powerful blow.

It seemed as if some of this waste might be obviated by working the air compound, using a different form of inertia valve so as to retain the good features of the device.

It was evident that a constant supply of initial pressure air should be furnished, available at any point of the stroke, but that it should have access to one end of the piston at certain specified times only, and that the valve should permit of opening a passage from this side of piston to the other, which necessarily should be of larger area to allow of the locked in charge of high pressure air acting expansively on both piston areas.

It was also a condition that during the movement of the piston under initial pressure that the other end of the cylinder should be open to exhaust in such a way that variability of stroke would result, and sufficient cushion formed to prevent piston striking cylinder head.

These conditions were fulfilled in a machine of the type shown in the illustration.

An annular groove was provided on a portion of the exterior of the piston that was in register at all points of the stroke with an admission port of high pressure air. An axial valve chamber was provided, open at the rear end in the body of the piston, having from it ports leading to the constant supply of motive fluid; other ports leading to a point adjacent to the small diameter of the piston and exhaust ports, arranged so that exhaustion could occur through them during the majority of the back stroke, but be closed by the motion of the piston for the remainder of the stroke.

A tubular valve was placed in this central chamber, having on its exterior surface an annular groove, so placed that when the valve was at the outer end of its travel, it would register with the ports from the constant source of supply, and the ports leading to smaller piston area, while at the same time a port through it would permit of exhaustion.

In action, the pressure against the small area of piston drives it back, air in the rear meanwhile having a free vent through the exhaust ports until the piston, in its travel, cuts off exterior exhaust port, thus cushioning the air remaining back of the piston and checking velocity of the piston when the valve moves by its inertia to the rear end of its travel.

In this back position the supply of high pressure air is cut off, as is also the exhaust port, and a port in the valve itself registers with the port leading to the small piston area, permitting the air locked in in front of the piston, free passage to the rear. The pressure immediately tends to equalize on both ends of piston, and owing to the larger area in the rear, the piston is forced out under the force of the expanding air from the front end of cylinder, continually decreasing in pressure as the piston moves, and the volume or space increases. The piston striking causes the valve to shift back to its original position, and the action continues.

It is obvious that if the piston were back when at rest there would be no locked-up air to expand, so that it could not start, and to overcome this difficulty, a spring is placed back of the piston just strong enough to force it out when no air is admitted. No loss of power results, as the energy stored up in it on the back stroke is given out on the

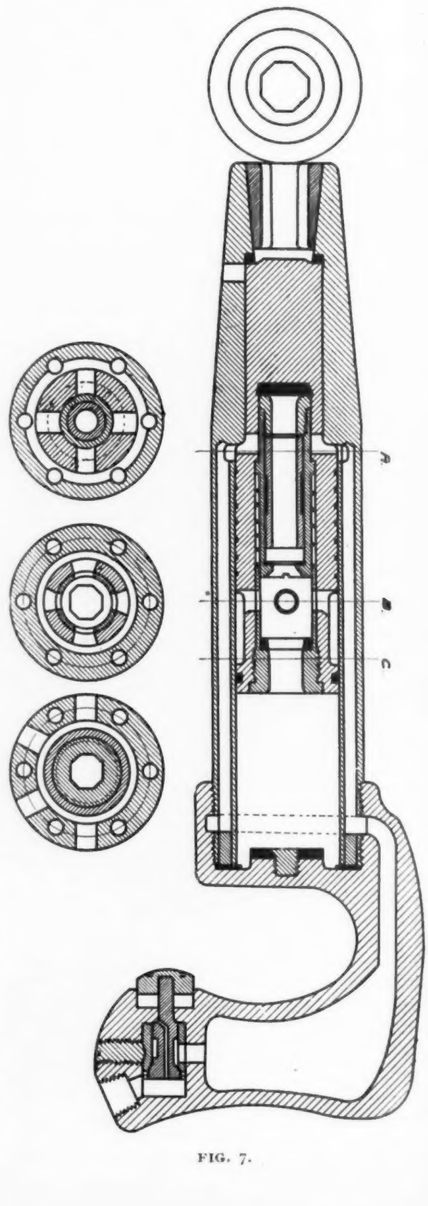


FIG. 7.

front stroke, and it serves to help cushion.

The valve also is provided with a light spring sufficient to keep it in the outer end of its travel when the piston is at rest, so that all will be in readiness to start on opening throttle valve. The inertia of the valve on the down stroke is sufficient when the piston is constantly accelerating in velocity, to prevent this spring closing the valve prematurely.

The proportion of expansion can be determined if the clearances are known, for any ratio of piston area. It has been found that for air the proportion of 10 to 3 is good, as this gives a terminal exhaust pressure of about 2 pounds per square inch if 80 lbs. were the initial pressure. This permits of prompt exhaustion, and no vacuum is formed in the rear, as would be the case if greater ratio of expansion were adopted. Such a ratio could be used with steam, as a condenser might be attached, but no experiments have been made in that line.

With this tool, about three times as much work can be done with the same volume of air as with a direct acting tool, exhausting at initial pressure, or the same work can be done with one-third of the volume of air. It may be seen that the diameters of the tool might have to be larger to effect these results, and that the mass of piston would be larger in consequence. In practice, a longer stroke has been adopted in order to avoid the back kick, due to large diameters, as explained earlier. The length of stroke does not affect the ratio of expansion, as the volumes in front and rear of piston change in definite proportion.

The velocities attained in forward and back strokes in either the compound or single acting hammers, can be calculated with fair accuracy when the diameters, piston areas, pressure per square inch, length of stroke and weight of piston are known, as these are constants or known variables. The amount of friction, leakage and loss due to overcoming inertia are difficult to determine exactly.

Knowing the velocities and the volumes of motive fluid used, the number of strokes per minute and the amount of air consumption, can be closely approximated, and in practice count of the number of strokes and accurate measurement of air consumption by meter, check out within from five to ten per cent. of the theoretical results figured.

Thus a tool can be intelligently designed to do the work expected of it, as regards force of blow, frequency of stroke, and air consumption at any given pressure.

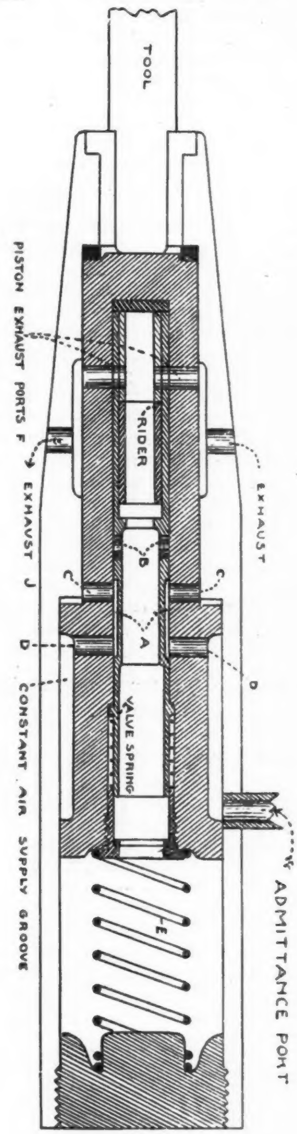


FIG. 8.

This valve motion would seem to be applicable to a great variety of purposes, even to running a compound engine with tolerable economy. The power of the stroke due to expansion is not 5 per cent. less than that due to initial pressure, on the small area, and a machine can be designed to strike by either initial pressure or expansive pressure, as desired. The latter has been chosen as giving simpler construction in the tool.

The valve motion described and the anti-bouncer arrangement are covered by several patents, as is the poppet valve tool described.

The tools, as now made, run very satisfactorily on long and severe tests, and are practicable and useful.

Endurance tests of materials and detail parts are now being made with the view of discovering all weak points.

When these have resulted satisfactorily, the tools will be put on the market.

Owing to the great number of strokes and the small cylinder volumes in the tools already experimented with, it has been impossible to make indicator tests, so a study of the action of tools was only possible by observation of action, air consumption and number of strokes per minute, as the valve itself could not be seen at work. It followed that by induction only could one arrive at the causes of some of the erratic performances and failures of the tools.

Compressed Air for Street Railway Operation.

Paper read by Mr. H. D. Cooke, President of the Compressed Air Co., at the annual meeting of the New York State Street Railway Association, held at Buffalo, N. Y., Sept. 18 and 19, 1900.

"Compressed Air for Street Railway Operation" is the subject assigned to me for treatment in this paper, and I find it difficult to place all the facts for an intelligent consideration of this subject before this convention in the twelve minutes allotted to me.

The question of liquid air was also coupled with this subject, but I do not deem it necessary to touch on this question more than to say that nothing has been accomplished in the manufacture of liquid air which will warrant its consideration as a factor in the operation of street railroads at this time. The present method of its production is to start with compressed air at 2,000 pounds pressure, and by expanding many volumes of air at this pressure, thereby producing intense cold, to liquefy a small volume of air. The only advantage which liquid air has is the small form in which it can be stored, 800 feet being compressed into one; but, on the other hand, as in this form it is the ice of air, the additional cost of heat necessary to return it to ordinary air for use in cylinders adds unnecessary expense. In other words, you cannot get out of a thing more than you put in it, and the expense in this case is prohibitive.

The subject matter of our theme therefore will be confined to the latest and most improved compressed air cars now in actual service in three cities of the United States, which are started, kept running and stopped by compressed air. When it is considered that one of the earliest applications of air in railroad service was its use for air brakes as a stopper of trains, it is passing strange that its use as a starter and stopper of trains did not earlier occur to mechanical minds.

Space precludes any general review of the past history of air, except to state that it was one of the earliest known of what may be termed the secondary forces or powers. Authentic records of the application of air are found among the writings of the Alexandrians, 300 years before Christ, and, later, water was used in connection with steam, but not much progress was made with either of these until the present century, during which such advances have been made in the manufacture of iron and steel, which have been used in the construction of engines, boilers, tubing, etc., as to make the use of steam the most important factor in modern life.

Although the application of compressed air to the propulsion of vehicles is of comparatively recent date, the fact that it is used in practically the same way as steam gives to it the benefit of all that has been done in the way of the perfection of the steam engine. In fact, there are many instances where steam boilers have been charged with compressed air and engines operated therefrom, and, in one instance, a locomotive was charged

with compressed air and run about the railroad yards and used for switching, etc. For such purposes, however, specially designed machines are better.

Limited space precludes any but the most general review of this important subject, and certainly nothing is more important to street railroads than the question of a power which can be economically applied to all conditions of service, and which is of so simple a character as to make its operation and maintenance equally economical. Recently, however, it has been given serious consideration and all the claims made for it have been fulfilled. It has proven itself reliable, unchanging, and where it has once performed a service it has always, under the same conditions, continued to perform that service. Unlike steam, compressed air does not have to be used as it is generated. It can be stored up and is ready for use when needed. Compressed to any required degree, it will always return to its normal atmospheric density.

Briefly described, the construction and operation of an air car are as follows, viz:

The most approved form of motor now in use in this country, and of which a number have just been constructed for the Metropolitan Street Railway Company, of New York, for their crosstown lines, consists of two small reciprocating engines underneath the car body, each connected directly to one pair of the car wheels according to the most approved form of locomotive engineering practice. The pair of wheels so driven are connected by parallel connecting rods to the other pair of wheels, thus making all the wheels under the car drivers. The air, before passing into the cylinders of the engine, passes through a reheating tank of water heated to an initial temperature of 300 degrees. The reheating of the air before use returns to it all, or a very great portion of, the heat units which were taken from it during compression. To illustrate this, a test was made of a motor in Rome, N. Y. This motor, which carried thirty-five cubic feet of storage, was run with cold air, until all the air was exhausted, and covered only eight miles. Afterward the same motor was run, using the reheating apparatus, and fifteen miles were covered. The heating of the water in the tank is done by attaching a steam connection directly from the boilers which furnish steam to the compressors, to the reheating tank on the motor and passing the live steam into the water.

In order that the minimum amount of difficulty might be experienced by the average motorman, a controller was devised which, in appearance and operation, is very like an electric controller. An air brake is one of the features of these motors, and an ingenious contrivance in the way of a starter is also controlled by the brake handle. The valve motion is exceedingly simple, and gives a range of cut-off of from 1-10th to 5-8th of a stroke. There is no appreciable exhaust and the operation of the motors is practically noiseless. The air brake used on these motors is operated from air stored on the car, and is absolutely noiseless, both in its application and release. Being operated by the same handle which starts the car, there is no danger of the motorman leaving his brake on and trying to start the car at the same time.

Cars of this type are in their sixteenth month of operation on the North Clark Street Cable line in Chicago, doing the night or owl service on that line, and sometimes hauling two trail cars. During the severe winter weather and snow storms which prevailed in that city last winter, the compressed air cars were the only ones to perform their regular schedule. Compressed air cars have been in use in France for several years, and also in Switzerland, and in some places in those countries are used to haul two and three trail cars, but the American motors are pronounced by both our own engineers, and engineers from other countries, to be far superior to those of European manufacture.

The storage tubes under the car are of mild steel, capable of withstanding a pressure of 5,000 pounds to the square inch. Bottles of this character are used, both in the power house and on the car; the initial pressure in the power house being about 2,500 pounds and on the cars about 2,000 pounds, which pressure on the cars is, by means of a reducing valve, reduced to about 15 pounds to the square inch before going through the reheating tank and thence passing into the cylinders. It will be seen, therefore, that there is an ample factor of safety allowed by the storage tubes, and, while all pre-

cautions which can be, are provided, and it is apparent that the further the cars travel the greater the factor of safety becomes. The storage on the car is underneath the seats, or the car floor, and the cars, in appearance, resemble the standard Broadway, New York, cars, none of the storage or machinery being in sight, and no paying space is taken up by either.

We now come to the power house: Air compressors, driven by an economical stationary steam engine, or by water or other power, compress the air from atmospheric to 2,500 pounds pressure to the square inch, and as the air is compressed it is stored in a battery of steel bottles of the character of those above mentioned. During compression, however, great heat is developed and a system of water jacketing is used which reduces the temperature of the air to that of the surrounding atmosphere. By means of a special separator, all the moisture contained in the air is separated from the air as it passes from the compressor to the storage, thus securing perfectly dry air. It is well known that expanding gas or air develops an exceedingly low temperature, but the use of the separator, removing all water from the air before storage, obviates freezing upon expansion, and the passing of the air through the hot water before use in the working cylinders restores to the air the heat units which were taken from it during compression and also furnishes enough moisture in the form of steam to assist in lubricating the cylinders. The exhaust from the engine cylinders never falls below 70 degrees.

In order to recharge the storage on the car it is only necessary to connect the storage in the power house with that on the car and equalize the pressure between the two. This is usually done at the end of a run, and while the car is waiting and takes about two minutes. In Chicago, however, this is done on the street and while the car is en route, and has never caused any delay or stoppage of the service, even though done while the air cars were running between cable trains.

During the last four years experimental and actual demonstration of air cars in service have reasonably determined the following facts, viz:

That the cars operated in Chicago during a period of six months consumed an average of 400 cubic feet of free air per car mile, and that the cost of maintenance of these motors is much less than that of the ordinary steam engine, as there is no boiler to be cared for.

We have been furnished figures by the most responsible builders of air compressors in this country, estimating on a volume of 6,800 cubic feet of free air per minute, which should be sufficient to operate 100 cars, which show that 2 8-10 cents will compress 1,000 cubic feet of free air to 2,000 pounds pressure. This estimate is approximate for local conditions, and coal is figured at $2.90 per ton for a twenty-four hours service, taking two pounds per hour for indicated horse-power. This includes attendance of engineers, helpers, firemen and laborers, and also for oil and waste, and allows for 10 per cent. per annum for depreciation.

The cost of equipping with air cars varies according to local conditions, but in the present state of the art is approximately the same as the overhead trolley. It is believed that the cost of operation and maintenance through a term of years will prove to be very much less, and that increased facilities of manufacture will greatly lessen the first cost.

It is believed that compressed air cars have a place in every large system already installed, whether cable or electricity, either for performing night service where it is not advisable or economical to run a large plant for the operation of a small number of cars, or where feeders or crosstown lines are necessary and the installation of the overhead or underground trolley would not be permitted.

In brief, the advantages of compressed air for the operation of street railways may be summed up as follows, viz:

First—A system of independent motors, which, after receiving their charges, do not rely upon the power plant and which will always finish their run should anything happen to the power plant; which also do not need any special outdoor construction, either underground or overhead, with the attendant cost of maintenance.

Second—Slow moving machinery, both in the power house and on the car, which is easily maintained.

Third—Opportunity for charging cars, and storage in power house, during light hours, for use during rush hours.

Fourth—Spring supported motors and load, doing away with excessive jarring and pounding on track, and thus greatly prolonging the life of the roadbed, the life of the motors, and contributing to the easy riding of the cars.

Fifth—Low first cost of plant; low cost of maintenance, and opportunity for making repairs and adjustments without stopping the operation of the cars.

Sixth—Freedom from liability in transit from snow, ice or sleet.

Report on the New Hardie Air Motor Cars now in use on the 28th and 29th Street Line, New York City.

September 18th, 1900.

MR. CLARK,
No. 621 Broadway,
New York City, N. Y.

My Dear Mr. Clark: Agreeable to your wish, I have the honor to report to you that I have inspected the Hardie Air Motor, now in service on 28th and 29th Streets, New York City.

Motor: A four wheel Air Motor, about 20 horse power. Cylinders, 6½ inches by 12 inch stroke. Four driving-wheels, 26 inches in diameter; steel tired.

Rigid wheel base, 8 feet.

Weight of iron frames, pedestal jaws boxes, shoes, wedges and binders—all in good proportion, and same as the running gear of a steam locomotive.

Cylinders well secured to frames Guides, Crossheads, Linkvalve motion and valve gear with independent cut-off All parts easily to adjust and cared for. Wheels are connected by Crankpins, parallel rods and main rods to crossheads and pistons.

Frames: The frames are extended 6 feet and 9 inches from center of pedestals, making a total length of frame 21 feet and 6 inches.

Heater Tank: A heater tank, or "Cylinder" is placed between frames, as also are the air storage tanks and reducing pressure valve. All pipe connections are made in a good and workmanlike manner.

The storage tanks have a capacity of 55½ cubic feet of air, which is compressed to 2,500 pounds per square inch

Car body, 22 feet outside, with platform at each end, 4 feet.

Total length over all, 32 feet.

Seating capacity, 30 persons.

Total weight of Motor Truck, 11,000 pounds.

Total weight of car, ready for service, 19,000 pounds.

The body of car is fastened to Motor framing by elliptic springs, and Motor Frame rests on saddles and springs, which give the car easy motion over rough and uneven tracks.

Under side seats in car are placed air storage tanks, which are connected by piping to air storage tanks on Motor Trucks.

Also Pintsch Gas Tanks, from which the cars are well lighted by night. This light, so well and favorably known, needs no further comment.

On each platform is placed the operating mechanism consisting of reversing lever, throttle lever, air brake lever, hand brake, and valve for shutting off air storage. The simplicity of this operating mechanism makes it easy to control the movement of the car, and in appearance, that of electric motors.

The air brake is especially a new device, and commendable. It is easily operated, and very effective in braking power. It is noiseless and instantaneous, both in application and release—no noise or hissing of air, as in other air brakes. All other air brakes that I know of do not release until the brake cylinder is bled. It is a special feature of this brake that it releases first, and bleeds afterwards. The same air which applies the brake releases it without the aid of a spring, and without noise.

I will here state that the air brake valve performs other functions in addition to operating the brakes. One is to start the motor from a state of rest, and the other is to rapidly accelerate the speed of the motor from a state of rest to full speed.

It will be readily understood that, with an engine having two cylinders with cranks at right angles, if the cut-off is earlier than half stroke one crank may be on the dead centre and the other on the quarter, but cut off, the engine will not start. By moving the lever one position in the opposite direction from that required to apply the brake, air is admitted from the brake valve directly through the main valve, which starts the

engine, instantaneously and positively. By moving the brake lever still another position, air is bled from one side of a piston attached to the valve stem of the reduction valve, so that pressure acting on the other side of this piston assists the valve spring to hold the valve open, requiring a higher pressure to close it against the combined action of the spring and piston. This high pressure is just what is wanted to enable the motor to accelerate rapidly from a state of rest. As soon as the motor has acquired the necessary speed the motorman moves the lever to the normal running position, restoring the pressure behind the piston so that it is a gain in equilibrium, and the motor again is operated under the normal pressure.

The whole mechanism is ingenious and novel, and may be characterized as admirable.

The hand brake is similar to the street car hand brake, and is only an alternative in case of the air brake failing—and only to be used to complete the balance of the trip.

The car is nicely painted on the exterior and interior, and resembles in appearance the electric car.

The motor trucks are not exposed, being shielded by a lattice screen below the car body.

The air compressing station is situated at the foot of West 24th street, New York city.

A 1,200 horse power engine, operating four stage Ingersoll-Sergeant air compressors, with a capacity of 56¾ cubic feet of free air per revolution compressed to 2,500 pounds per square inch. This air is stored in reservoirs in the car shed, from which the reservoirs on the cars are charged to the same pressure. The charging a car with air, and the hot water tanks, or "superheater," requires an average of two minutes. The car is then ready for a fifteen (15) mile run.

I find that there is very little noise when the motor is first started, and after starting, entirely noiseless, and that there is no jerking motion. The motor is clean, and free from dust and oil.

The motor and car herein described, I think, will prove in service to be practicable, and each car with its power is independent. The air storage is automatically reduced to a working pressure of 150 pounds per square inch. Having the storage at 2,500 pounds, the reduction valve governs this pressure through all stages until it is reduced to 150 pounds.

I think the Hardie Motor will prove economical in maintenance, as all its wearing parts are well constructed and easily accessible for adjustment and repairs.

I have looked over the reports made by experts, and have every reason to think they are correct—showing compressed air power to be cheaper than electricity or any other motive power.

Safety: The air storage tanks are all tested to a much higher pressure than the pressure they are stored with for service.

It is my opinion, judging from the construction of these storage tanks, and the tests they are put to before they are placed in service, that there is no possible danger of explosion, and they should prove to be practically indestructible.

I see no reason why the Hardie motor should fail to prove itself a success as to economy, safety and efficiency.

Respectfully submitted.

W. L. HOFFECKER.

Experiments on the Reheating of Compressed Air.*

By William George Walker, A. M. I. C. E., M. I. M. E.

Mr. Patrick Y. Alexander, of Experimental Works, Bath, and the author have during the past few months, at Chiswick and elsewhere, carried out some experiments on the reheating of compressed air. Considerable economy can be obtained by reheating compressed air before admitting it to the engine. Reheating is accomplished by two methods:—(1) By passing the air through hot pipes heated by a furnace fire. (2) By passing the compressed air through water in a boiler at a temperature depending on the pressure in the boiler. The former is called the dry method and the latter the wet or moist method of heating. It has long been the custom in Paris to use a small stove, through which the compressed air is passed before being used in the motor. Prof. Unwin, F. R. S., states that "Prof. Riedler tried an old 80 horse-power steam engine in Paris which had been adapted to work as an air motor,

*British Association, Bradford, Section G.

and which was actually giving 72 indicated horse-power with compressed air at 5½ atmospheres. It was using about 31,000 cubic feet—reckoned at atmospheric pressure—or about 2,376 lb. of air per hour. This air was heated to a temperature of about 300 deg. Fah. by the expenditure of only 15 lb. of coke per hour. On a favorable assumption a steam engine working to the same power would have required ten times this consumption of fuel at least." Prof. Unwin also says that reheating has the practical advantage of raising the temperature of exhaust of the motor, and for the amount of heat supplied the economy in the weight of air used is surprising. "The reason of this is that the heat supplied to the air is used nearly five times as efficiently as an equal amount of heat employed in generating steam." The author and Mr. Patrick Y. Alexander have, during the past few months, carried out a number of experiments on the reheating of compressed air by the wet method, i. e., by forcing compressed air into a boiler containing water, when very economical results were obtained.

Last year Prof. J. T. Nicolson, D. Sc., M. I. C. E., carried out some very valuable experiments in Canada under the auspices of the Taylor Hydraulic Air Compressing Company. Prof. Nicolson experimented with five different methods of using compressed air in an ordinary steam engine of the Corliss type of about 27 indicated horse-power. (1) The air was supplied to the engine cold. (2) Steam was injected into the air in the main pipe before supplying it to the engine. (3) The air was injected amongst the water in the steam boiler and heated by mixing with the water and steam of the boiler before being supplied to the engine. (4) The air was blown upon the surface of the water in a steam boiler and heated by mixing with steam in the same, before being used to drive the engine. (5) The air was passed through a tubular heating vessel and heated by a coke fire, afterwards being used to work the engine. The compressed air was drawn at a pressure of 53 lb. from the 6-in. main air pipe of the Taylor air compressor. The author gave an account of this compressor at the Bristol meeting of the British Association, 1898. The wet heating was carried out in a Lancashire boiler 7 ft. diameter by 30 ft. long.

Experiments were first made without reheating, when about 850 cubic feet of free air were used per indicated horse-power per hour. The air was then heated to 287 deg. Fah., by passing the compressed air through pipes heated by coke, under which condition 640 cubic feet of free air was used per indicated horse-power per hour, being a reduction of 210 cubic feet of free air per indicated horse-power per hour, due to reheating. Thus a saving of 25 per cent. is effected in the quantity of air used. This saving was effected by the burning of 348 lb. per horse-power hour. The results may be stated as follows:—100 horse power in cold compressed air was raised to 133 horse-power when reheated to a temperature of 287 deg. Fah., by an expenditure of 47 lb. of coke per hour, or at the rate of 1.42 lb. of coke per horse-power per hour additional. This is equivalent to an additional horse-power for every pound of coal burnt in the heater, which is far more economical than the most efficient steam engine and boiler. By mixing from 10 to 15 lb. of steam per horse-power with the air, the quantity of air required was reduced from 850 cubic feet to 300 to 500 cubic feet per indicated horse-power per hour. The results showed that the extra horse-power due to heating by the wet method was obtained at an expenditure of 1,3 lb. of coal per additional indicated horse-power per hour.

The author's own investigations are most conclusive as to the efficiency of reheating, either by the dry or wet method. Generally speaking, the results show that an additional horse-power can be obtained with an expenditure of 1 lb. of coal. Better results even than this have been obtained, which is far more economical than the most efficient engine and boiler using steam ever produced. And the experiments seem to show that in many cases it would prove advantageous to use compressed air in conjunction with steam in an ordinary engine.—The Engineer, London.

Compressed Air for Transmission of Power.*

By J. H. Ronaldson.

The transmission of power, to a greater or less distance, is frequently a subject for the serious consideration of a mining engineer, and thanks to the advances in scientific and mechanical knowledge made during recent years, the choice of method is varied and the possible efficiency is considerable. The means of transmitting power are steam, water, wire rope, electricity and compressed air, and the advantages and disadvantages of each of these systems vary with the distance to be bridged and the conditions attending their application.

Steam.—Within moderate distances and under certain conditions, steam is at once the most economical and satisfactory means of transmitting power, but the limitations to its use are too familiar to require enumeration.

Water.—There is no more valuable agent than water for actuating hoists and for certain pumping operations in mines, where excessive lifts over long distances have to be overcome. One of Moore's pumps has been in use at South Bulli Colliery, Illawarra, for some years.

Wire Rope.—For the general purposes of haulage, wire rope transmission of power is unexcelled, and it has in many instances been used for other purposes, such as pumping in mines. For the latter purpose it has, however, received a limited application, a result due, it is to be feared, to defective installation, through a frequent ignorance of the properties of ropes and pulleys. When one remembers the admirable work done in the way of haulage, pure and simple, by modern ropes, it is inconceivable to think that this method could not be applied to pumping in mines, in many instances with favorable result. As an example it may be mentioned incidentally that at the Metropolitan Colliery in New South Wales, a band rope of crucible steel 1¼ in. diameter, taken down a shaft 1,100 ft. deep, and transmitting at least 100-horse power regularly for ten hours per day, worked without change for five years and was then only taken off to insure perfect safety in an important service. The rope was far from being worn out when changed.

Electricity.—As a competitor with compressed air, electricity occupies the first place. Its use as a means of transmitting power has of recent years been widely extended, and in mines we have it now applied to pumping, haulage per medium of locomotives, and fixed rope haulage engines actuated by electricity, winding above and below ground, to rotary and percussive drilling, and most successfully to coal cutting machinery.

Compressed Air.—For the transmission of power this agent has therefore in certain directions serious competitors, in favor of which there has frequently been urged greater economy in first cost, in working cost, in efficiency and in applicability. These claims have, however, been keenly contested by the advocates of compressed air who, on the other hand, contend that it supplies a means of power transmission at once safe, economical and efficient for general mining work. The force of this contention has been much increased by the improvements effected during the last twenty-five years, in the methods of generating compressed air and of using it, as will be shown later on. There is little need to dwell on the importance of compressed air as a factor in the economy of many mines, an enumeration of its uses making this sufficiently apparent. It is used to actuate rock drills, underground haulage and hoisting engines, pumps, underground ventilating fans, Körting's air injectors, and coal cutting machines. It is necessary to an intelligent appreciation of the subject to consider the laws relating to air as a gas, and the mechanical causes which render its economical use more difficult than would at first sight appear. It is proposed, therefore, to consider the subject in the following order:—(1) The laws affecting the compression of air; (2) the various styles of compressors; (3) the causes of low efficiency in air compressors; (4) air conduits; (5) methods of using compressed air; (6) dangers attending its use.

1.—Laws Affecting the Compression of Air.

Air is an elastic fluid which, when free from vapor, behaves as a perfect gas; 13.09 cubic feet at ordinary atmospheric pressure, and at 60 degs. Fahr., weighs 1

*A paper read before the New South Wales Chamber of Mines, June, 1900.

lb. According to Boyle's law, the volume of a gas varies inversely as the pressure affecting it so long as the temperature remains constant; consequently in doubling or trebling the pressure the volume becomes one-half or one-third respectively. According to Charles' law, if the volume of a gas be kept constant, the pressure varies as the absolute temperature, and if the pressure be kept constant the volume varies as the absolute temperature. By the law of the transmutation of energy, work performed on a body, whether solid, liquid or gaseous, is evidenced by a definite increase of temperature in that body, and we are familiar with that fact as shown in the simple laboratory experiment of exploding a small charge of guncotton in a strong glass cylinder through the rapid heating of the air contained in it by a sudden jerk of a tightly fitting piston. Consequently when air is compressed it is heated; when heated it expands, and the volume of air to be compressed is proportionately increased with a corresponding expenditure of the power required to compress it. Could the temperature of the air undergoing compression be kept constant (isothermal) during the process, and the heat taken up from it returned to the air during its expansion in the motor while doing work, all loss from this source would be avoided. This, however, is impossible, and the aim of modern compressors is to prevent an increase in the volume of the air by keeping down the temperature during the period of compression; that is, by approximating to what is termed the isothermal process. It is clear that the least efficient compressor is the one in which no provision is made for cooling the air during the actual period of compression, that is one working on what is termed the adiabatic process.

2.—Air Compressors.

Although compressed air had been used to a small extent previously, it was not till 1850, when the Mont Cenis tunnel was constructed, that its use became general. Two forms of compressors are in use, in each of which a reduction of the temperature of the air is aimed at; in one case by the use of a liquid piston in the cylinder, and in the other by a water-jacket round the cylinder, or by an internal spray of water. The former is termed a "wet" and the latter a "dry" compressor.

Wet Compressors.—Of these there are two types: (a) where the water piston owes its energy to the fall of water from a height; (b) where the water piston is actuated by a steam driven piston. At Mont Cenis, Mons. Sommeiller made use of water with a fall of 86 ft., and by utilizing the momentum of the falling water he was able to obtain an air pressure of 75 lb. per square inch. Though extremely low in efficiency (not more than 6 per cent.) and necessitating clumsy plant, the arrangement gave results sufficiently good. This principle has been applied in other cases, and one arranged by Hathorn, Davey & Co., Leeds, was successfully used for many years in Mexico. The application of the principle is simple, and where an abundant water supply exists, excellent results are obtained. The second form of wet compressor has attained a wide application on the continent of Europe where, particularly among the highly educated Belgian and French engineers, the principles of air compression are more thoroughly understood than in Britain. It is, however, a question if their adherence to this method is not an instance of the length to which a desire to reach an ideal perfection may lead one from the best practical solution of a problem. As will be shown later on, the dead space at the end of the air piston stroke is undesirable, and it was largely to eliminate this defect and to keep the air cool that liquid pistons had such a vogue on the Continent. The water forced back and forward in the cylinder and up the pipe at each end, carrying the necessary valves, filled the dead space. But unfortunately for this ideal, there are a number of inconveniences attendant on the system. The cooling of the air is insufficient because it is only on the surface of the water. The speed of the piston is extremely limited and cannot exceed forty to fifty feet per minute, on account of the mass of water to be moved; consequently the number of compressors required for a given work is large. The water agitated by the motion is frothed and causes an excessive moisture in the air. Various devices more or less successful have been used to lessen these defects, but, in spite of all, the fact remains that in other countries these compressors have not found favor.

Dry Compressors.—This type of compressor has a cylinder and piston similar

to those of a steam engine, with suitable outlet and inlet valves at the cylinder ends. The temperature of the air is kept within reasonable limits by the constant flow of cold water through the water jacket of the cylinder from the bottom upward. It is, however, doubtful if this process of cooling, even under the most favorable conditions, does more than keep the cylinder from becoming excessively heated and so imparting heat to the incoming air. A more thorough method of cooling is obtained by injecting a fine spray of cold water into the cylinder near the outlet valves. To this the objection has been strongly urged that the presence of water with its non-lubricating properties causes an undue wear and tear in the cylinder and loss in power.

3.—Causes of Low Efficiency in Air Compressors.

These causes briefly stated are the heating of the air during compression, mechanical defects in the inlet and outlet valves, and leakage past the piston. It has been already shown that air when subjected to compression is heated, and that as the volume is thereby increased, much power is uselessly expended in dealing with the heated air. The most efficient compressor therefore, in this regard, must be the one presenting the best cooling arrangement for the air as it is being compressed. That form of compressor in which the piston is represented by the falling water supplying the power, such as Sommeiller's, permits of a very thorough cooling, as the water piston is renewed each stroke, and the cylinder is kept perfectly cool.

But in the second form of wet compressor, such as Dubois' of Mariehaye Colliery, Belgium, in which the water, only slightly renewed per stroke, becomes considerably heated, the cooling is not more perfectly effected than in the dry compressor. As the pressure to which the air is raised becomes greater, the losses from this source become serious, and as the efficiency of the motors increases with the pressure, and the size of the conduits can be correspondingly small it is desirable, particularly in large installations, to use high-pressure air. The most satisfactory results in this direction have been obtained by stage compression —that is, by pressing the air to a certain pressure in one cylinder and further compressing it in a second, and, if desired, in a third, or even a fourth. By this system the air is cooled between each stage, and the losses from this source are minimized. For low pressures it is doubtful if any practical economy would result from stage compression, but it is now fully demonstrated that for pressure above 60 lb. the advantages of stage compression are very marked. To diminish losses caused by resistance to the passage of the air through the inlet and outlet valves many devices have been resorted to. In the ordinary valves held to their work by springs the valves rattle or chatter if the springs are weak. On the other hand, if the springs are made very strong, a resistance to the passage of the air is set up, resulting in a loss of power which in some cases becomes serious. To obviate this defect the valves are occasionally devised to open mechanically. In a short paper such as this it is impossible to enter into the details of the various valves used. It is not uncommon to hear much stress laid on the losses caused by the unavoidable dead space occupied by compressed air at the end of each stroke, and it may be pointed out at once that the loss is not in power, but solely in the volumetric capacity of the compressor. To diminish this inconvenience, the air piston is usually run as close to the cylinder ends as practicable, and care is requisite to avoid sailing too close to the wind in this direction and damaging the mechanism. The best plan is to arrange trick passages or grooves on the inside of the cylinder, for a short distance back from each end, to allow the air in the dead space to pass the piston to the end in which compression is about to begin. The inside pressure against the suction valves is thereby relieved, and compression on the other side of the piston begins at once. To prevent knocking, through the sudden relief caused thereby at the end of the stroke, a certain amount of cushioning in the steam cylinder is required. The low efficiency, due to leakage of the pistons, can only be effectually reduced by carefully attending to their condition. Naturally the higher the compression the greater the leakage; but stage compression greatly lessens this evil.

4.—Air Conduits.

Two considerations are of importance in determining the pipes to be employed; these are the size of the pipes and the character of the joints. The frictional

loss in the passage of the air through the pipes increases very rapidly as the diameter decreases, as shown by the following example. If a volume of air at 60 lb. pressure, equivalent to 18,000 cubic feet per hour at atmospheric pressure, be passed through 1,000 ft. of pipes the loss of pressure of air for 2½ in., 3 in., 3½ in. and 4 in. pipes would be 5¾ lb., 2 lb. and 1½ lb. respectively. Leakage at the joints, through the expansion and contraction of the pipes, is a fruitful and at times a serious source of loss of power. A receiver of suitable size should always be placed alongside the compressor, and where a considerable length of pipes is used, it is an advantage to have a receiver as near the motor as practicable.

5.—Method of Using Compressed Air.

When air is compressed it is heated, and when it expands it is cooled. The latter fact gives rise to the inconvenience so frequently met with in air motors, of ice being formed in the ports, through the freezing of the moisture in the air. Where the air is admitted to the motor practically during the whole stroke there is little danger of ice being formed, but there is a terrific waste of power, for it is as important for economy to use air expansively as it is to use steam expansively. While a little moisture in air used expansively results in the formation of ice in the ports, it may be pointed out that aqueous vapor has a specific heat nearly double that of air, and consequently cools less rapidly under expansion than dry air, and the tendency of an excess of moisture is to reduce the cooling. The specific heat of water being still greater, a spray of water may be effectively used in the motor cylinder to prevent cooling to the freezing point. The writer was familiar many years ago with an instance where, in the case of large haulage engines placed underground, the inconvenience caused by freezing was so serious that compressed air was abandoned, and steam, though inconvenient, was substituted. Reheating the air is, however, the most effective method of allowing air to be used expansively, without the formation of ice in the ports, and this can best be done by passing the air near the motor, through a coil of pipes heated by a small furnace; and a further elaboration, permitting the highest degree of expansion, is effected by introducing a small quantity of water into the heater, where it is converted into steam. A move in the latter direction was made years ago by the use of a jet of steam in the air pipe, near the motor. In practice it is found that reheating the air not only prevents freezing, but results in a very great economy in the use of compressed air at a small cost both for plant and fuel.

6.—Dangers Attending Its Use.

These are so slight as to be scarcely worth considering, but their existence is worthy of passing notice. A few cases are known where an explosion, more or less marked, has occurred in the receiver placed near the compressor. In these instances combustion has been set up apparently in the carbonaceous matter, deposited from the lubricants used in the compressor. The readiness with which a piece of old oily waste takes fire at comparatively low temperature is well known, and it is possible that a similar action may take place in the deposited carbon, if subjected accidentally to abnormal heating by a failure in the cooling apparatus of the compressor.

The use of compressed air seems at first sight an extremely simple one, and consequently the principles surrounding its use are seldom inquired into. The results obtained from it are, in consequence, at times appallingly poor, and its reputation as a means of transmitting power suffer proportionately. In the worst forms of machines 10 per cent. only of the power expended may be obtained, and the writer has a distinct recollection of the care with which his Belgian professor demonstrated the impossibility of obtaining more than 33 per cent. of useful effect from compressed air. But to quote from Professor Goodman: "In the best cases, without reheating about 55 per cent. and with reheating 75 per cent. of the total power is given out by the motor." The extensive use made of compressed air in metalliferous mines, particularly for rock drills, should naturally induce an intelligent interest in its use in Australia, and a discrimination in the proper and improper methods of employing it.

The Usefulness of Compressed Air Under Difficulties.

We show on the frontispiece a picture somewhat idealized representing the sinking of a caisson for the purpose of building a lighthouse at the mouth of the Potomac River, Chesapeake Bay.

A few years ago this lighthouse was built at what was known as Smith Point, a dangerous location where opposing tides and currents have built up shoals of sand which extend eight or ten miles out into the Bay. Severe wrecks had occurred on this shoal until it was determined to put a light just at the edge of the channel about eight miles from the shore and about one hundred and twenty miles south of Baltimore. The work was begun in 1896 and completed in about one year. The sinking of the caisson was the most difficult part of it and this was almost impossible except through that valuable auxiliary—compressed air. The caisson was such as is usually employed and an air compressor, boiler and other appurtenances were placed on the top and somewhat exposed to the waves during the storms. This work was successfully accomplished, the air being used to give life to the men beneath the surface who dug within the great iron cylinder until it rested upon a secure foundation. So long as the air compressor was kept working on the surface all was peace below, where the storms were not felt.

This is only a type which emphasizes the importance of compressed air in this valuable field of foundation building. Foundations for bridges are built in the same way and it would be difficult to find a means by which the huge difficulties encountered in this kind of work would be overcome without the aid of compressed air.

The Yeakley Vacuum Power Hammer.

The Yeakley Vacuum Hammer Company, of 3 Rochester Row, Westminster, have installed at the works of Messrs John Mowlem & Co., the contractors, of Westminster, one of their new vacuum hammers, the working of which we recently inspected. In this hammer a vacuum is used to stop or control a falling weight. And it has been designed to do light and heavy forging in iron and steel without any variation of speed. The hammer head or ram is actuated by vacuum and pressure, and controlled by a simple valve mechanism that responds to the slightest touch, being so sensitive that the pressure of a finger on the treadle is sufficient to operate it. It is lifted by vacuum and driven down by air pressure. When the hammer is put in motion, the head or ram lifts up and carries perfectly still at the highest point of its range. It is held there by the vacuum, the air pressure being cut off by the valve. The balance wheels, pitman and piston are running, and the head is at rest. To make it strike, the valve is opened by operating the treadle, and the air pressure is admitted to the ram to drive it down. The instant the valve is closed by removing the foot from the treadle the ram remains up, or lifts up if the valve is closed when the head is down. As it can always be depended upon for one blow, it is available for drop forging. The hammer head acts both as ram and piston in front cylinder.

The principal points claimed for this hammer are that it strikes a light or heavy blow, at will of the operator, the regulation being obtained by the treadle, and gives a dead blow with pressure following clear down, thus preventing work moving about on the anvil. There is, of course, no piston rod to break, and no springs, helves, or rubber cushions to get out of order. The movement of the treadle is adjustable from 1 to 3 inches, and when the work is not too large, the operator can manage both work and hammer perfectly. The foundation is very simple and inexpensive.

The rams are guided on all four sides and have large die surfaces on all sides. This allows several dies or swedges to be placed on the ram together, and each can be used continuously, so as to do several operations in succession at one heat. In fact, this hammer has many of the features of a drop hammer. The large die surface and accuracy are suited to such work as has been done in board drops. The Yeakley hammer action is such that the ram comes down quicker than a drop hammer, but hangs an instant at the end of the stroke with full

pressure so as to kill the spring of the metal, so that it does not rebound to the same extent as a drop hammer.

The rams vary from 36 lbs. to 800 lbs in weight. The weight of the ram can be varied without interfering with the frame In the latest built the 150-lb. ram weighed 162 lbs., and the 400-lb. ram weighed 480 lbs.

In the smallest sizes the anvil is united with the main frame. In all others it is separated. The head or ram is represented as down, but it lifts instantly when the belt is thrown on the pulley and will strike the moment the treadle is depressed.

Iron and Coal Trade Review,

Spreader Car, G. C. & S. F. Ry.

A line of improvement which seems to be meeting with considerable development in maintenance-of-way work this season is the designing of spreader cars for leveling down earth or ballast at the side of the track. The car is the creation of Mr. E. McCann, general foreman of bridges and buildings of the Gulf, Colorado & Santa Fe R. R., where it has been put into service. The machine was built at the request of General Superintendent W. C. Nixon, who has kindly supplied us with data.

The machine consists of spreader wings fitted to an ordinary flatcar and provided with hoisting apparatus. The wings are of the ordinary heavy plank construction, faced with boiler plate and hinged to the car by means of heavy struts ironed off and well braced with angle irons. Each wing is divided into two sections, the rear section extending from the ends of the ties outward, and the forward section from the rail to the ends of the ties and overlapping the rear section. The intention of the forward section is, of course, to clear away material from the rail and uncover the ties, while the rear section cuts to a depth even with the bottom of the ties, or below if desired. The front section is hinged to a heavy bar extending diagonally across the corner of the car, and a piece of stout chain is attached to the rear section to take the longitudinal stress. The side pressure against the front section is received by a hinged strut, which abuts against a stop block bolted to the under side of the end sill of the car. The side thrust against the rear section of the wing is received by struts abutting against heavy timbers extending across the car, underneath the sills. There is a heavy timber box at either end of the car for ballast loading, to hold the car to the track.

The apparatus for hoisting the wings consists of four 8-inch cylinders mounted upon the top of a framework which is sufficiently high to clear the wings in their raised position. These cylinders operate pistons which have a travel of about 5 feet, and the piston rods are fitted to a cross head, to which are attached two pulleys, around each of which is doubled a wire cable for hoisting the wing on one side of the car. The pistons thus pull the end of the cable a distance equal to twice the travel of the piston. The wings are operated by one man, who stands upon a platform suspended from the top of the frame and handles the air cocks of the cylinders. The air for operating the hoisting cylinders is taken from the brake system of the train, air storage being provided for by a reservoir located at one end of the car, on top of the ballast box. The cable for lifting the wing on each side is attached to the rear section, which also lifts the forward section, which comes to rest in a notch in the corner of one of the posts of the A-frame. In lifting the wings they are revolved past the center and thus rest in stable equilibrium. In lowering the wings to position they are shoved over the center by means of a lever and dropped to working position by gravity, being controlled in their fall by air in the cylinders. The wings can be put into working position within a minute from the time the car stops for that purpose, and in passing over bridges or cattle guards they can be raised to clear in a very few seconds, and let down again into working position without requiring the train to stop. As a precaution against any failure of the air supply a rope tackle is suspended from the framework for hoisting the wings in case of necessity.

The machine was built to prepare banks to receive the ballast after having been widened out by material unloaded from trains. The machine has been in operation for about four months, during which time some minor improvements have been made, one of which consists of a roller on the forward section of the wing,

to prevent the end of the wing from scraping against the rail and also to permit it to pass safely over rail braces and joint splices. In the use of machine dirt has been leveled down on the shoulders for a distance of a half mile in 13 minutes from the time the engine stopped to begin work until the machine was folded up to clear. The operation of the machine has been found to be so satisfactory that others will be built for the work of this company. The present machine was built in the company's shops at Cleburne, Tex.

Railway and Engineering Review.

Megaphones in Fog Signaling.

Lighthouse Board Experimenting With New System for Benefit of Mariners.

The Government Lighthouse Board is making experiments with a new system of fog signaling at Falkner's Island, in the Sound, near the Thimble Islands, beyond New Haven, Conn.

The principle of the new invention was tested last year and found correct, and this year the complete apparatus has been put up. It consists of eight megaphones, ten feet long, each directed to a different point of the compass. The small ends of these eight megaphones meet in a ring, inside which is a revolving cowl, which turns on the top of a siren. The siren is kept constantly spinning at the rate of two thousand revolutions a minute, and when compressed air is admitted to it it gives forth a very penetrating and far-reaching sound about C in the middle octave.

Compressed air is supplied to a large reservoir by an oil engine which runs at high speed. From this reservoir the air is taken to the siren through an oddly constructed valve by means of which a current of air at a pressure of two hundred pounds, passing through a two-inch pipe, can be controlled by a touch of the finger. This valve is operated by a series of teeth on a signal wheel, which revolves slowly, producing different signals as each of the different megaphones comes into range of the revolving cowl.

These signals consist of long and short blasts, the long ones being three seconds each and the short ones one second each. The eight points of the compass are distinguished by the difference in these signals. Opposite points have exactly opposite signals, that for north, for instance, being one long blast and for south one short blast. For east it is one long and one short, and for west one short and one long. For southeast it is one long and two short, and for northwest two short and one long. For southwest it is two short, and for northeast two long.

These signals announce to the mariner the direction from which the sound comes, so that if a vessel was passing Falkner's Island and heard two short blasts it would know that Falkner's Island must be southwest of it. It could not hear any other signal but the one pointed toward it, because the megaphones send the other sounds in a different direction; but if the vessel were to keep on its course until Falkner's bore due west it would then be unable to hear any signal but the short and long blast which signifies west.

These signals were suggested by Col. D. P. Heap, engineer of the Third Lighthouse District, at Tompkinsville. The principle of the invention, which consists in sending sounds in a certain direction to the exclusion of other directions and the apparatus by which the signals are worked are the invention of R. F. Foster of New York.—New York Herald.

Notes.

At the annual meeting of the Westinghouse Air Brake Co., held in Pittsburg, Oct. 2, Henry W. Oliver was elected a director, succeeding the late A. M. Byers.

The McLaughlin Automatic Air Brake Company will be organized to make the McLaughlin air brake. The capital will be one million dollars, and the headquarters will be either Windsor or Walkerville.

The stockholders of the American Air Power Company have formally voted to

dissolve that corporation. This is one of the steps in the amalgamation of the various companies into the Compressed Air Company, concerning which our readers have already been informed.

The pneumatic staybolt clipper of the Helwig Mfg. Co., St. Paul, Minn., was recently placed in the shops of the Great Northern Railroad at St. Paul, and is reported to be giving most excellent satisfaction. The company is having a large sale for these staybolt clippers, and it is meeting with approval wherever it is installed.

At the Burnside shops of the Illinois Central Ry. shops experiments with pulverized coal for fuel have been lately carried on in a stationary boiler. The ordinary coal is ground to a fine dust and is sprayed into the fire box with air pressure. It is understood that favorable results are being obtained, though the tests are not yet complete.

At the Columbus shops of the Pittsburg, Cincinnati, Chicago & St. Louis Ry. a flat car is being fitted with an air compressor and boiler, together with such other apparatus as is necessary to furnish a sand blast. The car is to go out on the road and clean bridges and other iron structures by means of a sand blast as a preparation for painting these structures.

The Rix Engineering & Supply Company, of San Francisco, Cal., has placed on the market a small compressor for electric station equipment. This compressor is intended to blow the dust from electric machines of all kinds, and has a capacity for running one small pneumatic tool if such is required. It is valuable for testing pipes, blowing dirt through castings and any other service where a small amount of air at moderate high pressure is required.

Fourteen new compressed air motors of a heavier and more highly developed type are now making trial trips on the Eleventh avenue line of the Metropolitan Street Railway, and the experiments are reported to be very satisfactory. During one of the heavy snow storms in New York City two years ago, when cable and electric cars were blocked to a standstill, the air motor cars bowled bravely along and proved their staying qualities in the heaviest kind of weather.

The Chicago Pneumatic Tool Company has recently made arrangements to have all repairs of their tools made at their works at Olney, Philadelphia, for customers who are located within the territory convenient thereto. Heretofore the repairs to machines and the repair parts for the Boyer tools have been made in St. Louis. The Boyer plant has recently been moved from St. Louis to Detroit, and much enlarged, in order to enable the company to keep pace with the many orders they are receiving.

The exhibits of pneumatic tools at the Paris Exposition attracted more attention than any other special line, the appliances having been adapted to so varied a line of work as to be entirely novel, ranging from heavy drilling in armor plate to the lightest carving in stone, or boring and sawing wood. The hammers range in power from the minimum. Two gold medals were awarded to one company (Chicago Pneumatic Tool Co.). Foreign builders realize that they must use these tools to compete in the markets of the world.

On the Mobile & Montgomery division of the Louisville & Nashville an order has been issued that passengers must not hereafter be carried on freight trains. It is said that this order is issued in consequence of the difficulty, since the general introduction of the air brake on freight trains, of moving the rear portion of trains smoothly enough to avoid injuring passengers. In a number of cases passengers have been injured while riding in cabooses, particularly on trains in which only a part of the cars were controlled by the air brake.

Mr. John B. McDonald, contractor for the underground railroad, in New York City, in speaking of the work, says: "There is one important point about the rapid transit work which I would like to emphasize. I refer to the manner in which it is being conducted. We are trying to save the public from nuisance and inconvenience at every

point. We have placed at various points compressed air plants. The use of compressed air does away with a lot of independent boilers on the works, and a great deal of smoke and noise is eliminated. Compressed air works the drills, taking the place of steam. The use of air in place of steam facilitates the work to a certain extent and, besides, it is cleaner and less noisy. There is a large compressed air plant at Union Square, another at Forty-second street, and others are being established where needed. One plant can supply power to a number of different excavations within a certain radius."

We have received from the Westinghouse Company copies of two publications which they have recently issued, and which well merit the attention not only of engineers and scientific men, but also of all lovers of beautiful specimens of the bookmakers' art. One publication, entitled "Electric Power," intended for distribution at the Paris Exposition, is printed in four languages, and contains a collection of views of Westinghouse motors applied to stationary service. The pictures speak for themselves, and explain some of the many ways in which these motors are used for industrial p poses. The book is gotten up in a very handsome and attractive form; it is printed on heavy paper, the cuts are remarkably fine, and the whole publication warrants close inspection. The other catalogue, called "Drop in Alternating Current Lines," treats of a method for calculating drop in alternating current circuits, and should be of considerable interest to engineers who have calculations to make. Copies of these two publications will be sent on application to the Westinghouse Company.

M. A. Mosso, in a recent communication to the French Academy of Sciences, on the physiological action of compressed oxygen, recounted some experiments which he had made on animals that seemed to indicate for this substance great value in cases of poisoning by carbon monoxide (CO).

Two monkeys were placed in an atmosphere containing 1 per cent. of this gas. At the end of half an hour both were completely poisoned, their respiration being almost entirely suspended. They were then removed from the co atmosphere; one of them left in the ordinary air, and the other placed in oxygen compressed to two atmospheres. The first one died only a few moments after removal from the poisoned chamber. The monkey in the compressed oxygen almost immediately regained consciousness, and at the end of half an hour was removed to the ordinary air and seemed to be perfectly recovered. It frequently happens in mine explosions that the imprisoned workmen are alive when rescued, and live several days, only to finally succumb. According to M. Mosso, these men could be certainly saved if they were, immediately after their rescue, placed in an atmosphere of compressed oxygen; and he believes there ought to be a specially prepared chamber for this purpose as a part of the regular mine equipment.

The following letter is from a gentleman who was for a good many years chief engineer of two elevated railroad companies and who is consequently pretty well qualified to speak for city traction matters:

"On Saturday afternoon, September 22, I happened to be on Twenty-third street and noticed one of the cars passing, run by compressed air power. I watched its operation with others most of the afternoon. They move along splendidly, and with much less noise than those run by electricity, especially as they pass the rail joints. When rounding a curve you can scarcely hear them; no jerk when power was shut off. They stop in a much shorter length of track than the electric cars. When the trolley cars are going under full headway they are noisy. The air cars under full headway make little noise. They leave no electric current in the ground to moth-eat the water pipes. The mechanical improvements which have been made since they ran on 125th street are great. I was impressed very much with the ease with which they moved along, and the apparently perfect control they were under by the motorman.

"More progress no doubt will be made in mechanical improvements in order to perfect their operation. It is clear to most any good mechanic that the system will, in course of a short time, be used quite generally on surface street roads."

Railroad Gazette.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz., all communications should be written on one side of the paper only; they should be short and to the point.

Boston, Mass., Sept. 18, 1900.

Editor Compressed Air.

Can you inform me where I can get a full description of "Orde's Liquid Fuel Burner" mentioned in your July issue? I shall feel very much obliged for any information you can give me upon the subject. Yours truly,

G. R. ELLIOTT.

New York, Oct. 17, 1900.

In your last issue of "Compressed Air" I note with interest the first article in that issue as having a very important bearing on the matter of proper lubrication in air compressor cylinders. Of course you know what we have done, and I will be very glad if you would consider more seriously than ever the necessilty for recommending proper lubricant for this particular work.

With very kind regards we beg to remain, Yours very truly,

FISKE BROS. REFINING CO.

F. B. Fiske, Vice-President.

PATENTS GRANTED SEPT., 1900.

Specially prepared for COMPRESSED AIR.

657,076.—CARRIER FOR PNEUMATIC TUBES. Birney C. Batcheller, Philadelphia, Pa. Filed June 16, 1898. Serial No. 683,549.

A carrier for pneumatic tubes having at its front end a spring-actuated latching device in combination with a contact-plate adapted to be engaged and locked on the front end of the carrier by said latching device.

A carrier for pneumatic tubes having at its front end a spring-actuated latching device in combination with a contact-plate adapted to be engaged and locked on the front end of the carrier by said latching device, and a keyhole leading to the latching device whereby a key can be inserted to unlock it.

A carrier for pneumatic tubes having at its front end an opening for the insertion of the shank of a contact-plate and a spring-actuated latch adapted to engage said shank in combination with a contact-plate having a shank adapted to enter said opening and engage said latch, and a keyhole formed through it whereby a key can be inserted to disengage the latch.

657,077.—CARRIER FOR PNEUMATIC TRANSMISSION SYSTEMS. Birney C. Batcheller, Philadelphia, Pa. Filed Oct. 1, 1898. Serial No. 692,380.

A carrier for pneumatic transit-tubes having a lid-seat situated within and at a short distance from the open end of the carrier and inwardly-projecting lugs secured to the end of the carrier so as to overlap the lid-seat, in combination with a lid adapted to seat itself on the seat inside of the lugs, said latch having notches in its edges to enable it to clear the lugs, a locking-bar centrally pivoted on the outer face of the lid and adjustable on its pivot from a position in which it clears the lugs in opening and closing to a position in which its peripheral edges lie beneath said lugs and lock the lid in place, and a spring-catch for holding the locking-bar in locked position.

657,079.—CARRIER FOR PENUMATIC TRANSIT-TUBES. Birney C. Batcheller, Philadelphia, Pa. Filed Nov. 8, 1898. Serial No. 695,832.

A carrier-cylinder having a tightly and permanently closed front end in combination with cushion-holding devices secured permanently to said closed end, a cushion and means for attaching the cushion secured to it and adapted to engage with the cushion-holding devices on the carrier, secured permanently to said closed end, a cushion and means for attaching the cushion secured to it and adapted to engage with the cushion-holding devices on the carrier.

657,090. — PNEUMATIC-DESPATCH-TUBE APPARATUS. James T. Cowley, Lowell, Mass., assignor to the Lamson Consolidated Store Service Company, Newark, N. J. Filed March 23, 1899. Serial No. 710,155.

657,091. — PNEUMATIC-DESPATCH-TUBE APPARATUS. James T. Cowley, Lowell, Mass., assignor to the Lamson Consolidated Store Service Company, Newark, N. J. Filed Dec. 21, 1899. Serial No. 741,111.

A pneumatic-despatch-tube apparatus, a carrier transmission-tube having an inlet and an outlet for the carriers, a valve for closing said inlet after the insertion of the carriers, a source of compressed air, an air-inlet for said compressed air, a valve normally closing said air-inlet, means for opening said air-inlet valve, means operated by compressed air for holding said air-inlet valve open, mechanism in the path of the traveling carriers adapted to be operated by the traveling carriers to release the air-pressure on said air-inlet-valve-holding means and thereby release the same to allow the closing of said air-inlet valve, and mechanism operated by air-pressure in the transmission-tube for allowing the escape of the compressed air from the air-inlet-valve-holding means.

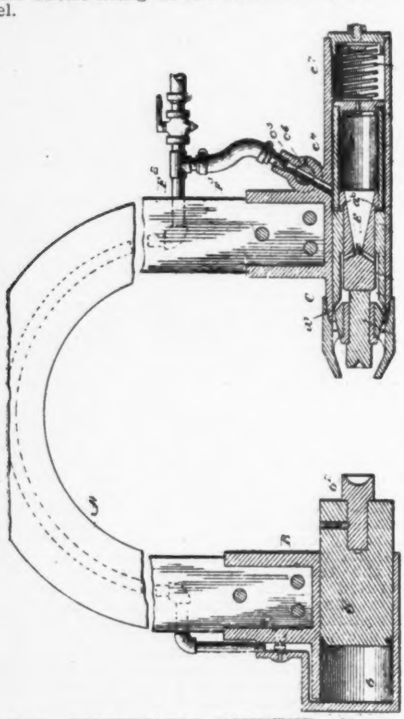
657,092. — PNEUMATIC-DESPATCH-TUBE APPARATUS. James T. Cowley, Lowell, Mass., assignor to the Lamson Consolidated Store Service Company, Newark, N. J. Filed May 8, 1899. Renewed March 12, 1900. Serial No. 8,398.

A pneumatic-despatch-tube apparatus, a carrier-transmitting tube having an inlet

and an outlet for the carriers, a valve for closing said inlet after the insertion of the carriers, a source of compressed air, an air-inlet for said compressed air, a valve normally closing said air-inlet, means for opening said air-inlet valve adapted to be operated to open said valve upon the closing of the valve controlling said carrier-inlet, means operated by compressed air for holding said air-inlet valve open, and mechanism in the path of the traveling carriers adapted to be operated by the carriers to release the air-pressure on said air-inlet-valve-holding means and thereby release the same to allow the closing of said air-inlet valve.

657,344.—PNEUMATIC GUN. Edwin M Goldsmith, Philadelphia, Pa. Filed Dec. 15, 1899. Serial No. 740,382.

A pneumatic gun, an air-chamber at the breech thereof, an outlet for said chamber to the atmosphere, a piston, a lever for moving said piston forward of said chamber, and means for forcibly returning said piston rearwardly to said chamber, said outlet being at the breech of the barrel.



657,449.—PNEUMATIC RIVETER. Herman H. Prange, Akron, Ohio, assignor to the Johnson, Parfitt Tool Company, Springfield, Ill. Filed Feb. 19, 1900. Serial No. 5,774.

The combination with a suitable supporting-casing, of a pneumatic hammer longitudinally movable in the casing, means for the admission of motive fluid to the casing and hammer, a plate-closer mounted on the casing, and means for holding the rivet and plates up to the plate-closer.

The combination with a suitable support, of a hold-on, a fixed casing, a pneumatic hammer longitudinally movable in the fixed casing, means for the admission of motive fluid to the hold-on and to the fixed casing and the pneumatic hammer, and a plate-closer mounted on the fixed casing.

The combination with a suitable support of a hold-on, a casing, a pneumatic hammer longitudinally movable in the casing, and a valved motive-fluid-supply pipe having branches leading to the hold-on and to the casing, the one leading to the casing having an independent throttle-valve.

657,669.—AIR-BRAKE. John J. Nef, New York, N. Y. Filed June 22, 1898. Serial No. 684,160.

An air-brake system, the combination with an air-reservoir of a pump and pump-operating mechanism, an automatic governor comprising a compound cylinder having piston-heads of different diameters corresponding with the bores of the cylinder, means whereby a pressure is constantly maintained in the small bore against the small piston-head, and means for varying the pressure in the large bore of the compound cylinder against the large piston-head, a clutch adapted to connect and disconnect the pump and pump-operating mechanism, and a clutch-lever operated by a connection between the piston-heads.

657,753.—AIR-ACTUATED PUMP. Frederick Z. Bartell, Sioux City, Iowa. Filed Dec. 22, 1899. Serial No. 741,241.

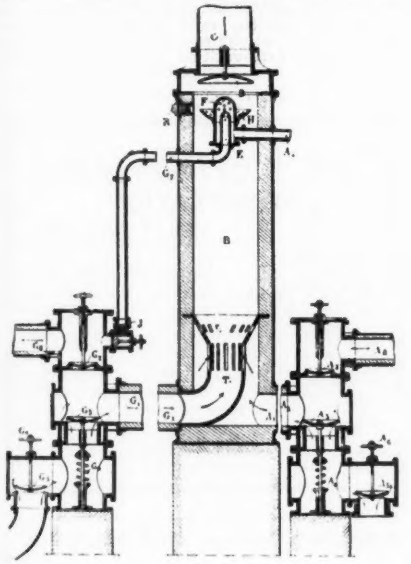
657,755.—AIR COMPRESING AND CARBURETING MACHINE. Adolphe Bouvier, Lyons, France. Filed March 9, 1900. Serial No. 7,956.

An air compressing and carbureting apparatus, the combination of a stationary outer cylinder or chamber, a hollow shaft traversing the same and having perforations in its walls, an inner drum secured to said shaft, means for rotating said shaft and drum, a spiral tube located on the periphery of said inner drum, a smaller drum located within the inner drum and forming an enlargement of one end of said spiral tube, said tube adapted to convey fluid from the outer cylinder to the inner drum, an offtake-pipe registering with the hollow rotatable shaft, and means for automatically discharging the surplus liquid accumulating in the inner drum into the outer cylinder.

657,868.—APPARATUS FOR USE IN COMPRESSING AIR AND GAS. Emile Gobbe, Jumet, Belgium. Filed Dec. 27, 1899. Serial No. 741,749.

An apparatus for compressing aeriform fluids, the combination of an explosion-chamber having a chimney provided with valve, an igniter in the upper portion of said chamber, a twyer located in the lower portion of the explosion-chamber and provided with lateral openings, a valved gas-pipe communicating with said twyer, the air-pipe A′ communicating with the explosion-chamber through the lateral openings of the twyer, the air-regulating valve A^5 and suction-valve A^3, the air-collector A^9 and the delivery-valve A^2 intermediate said collector and air-pipe

An apparatus for compressing aeriform fluids, the combination of an explosion-chamber having a chimney provided with a a valve, an igniter in the upper portion of said chamber, a twyer located in the lower portion of the explosion-chamber, the air-



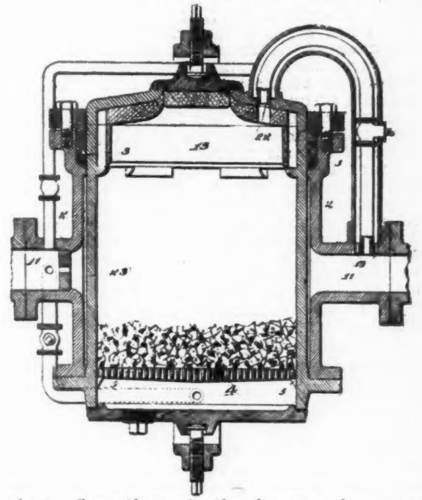
pipe A' having valves A^2 A^3 and A^5 the air-collector A^8, the gas-pipe G' having valves G^2, G^3 and G^5, and the gas-collector G^8, the said air and gas pipes being in communication with the explosion-chamber through the twyer.

657,886. — PNEUMATIC-DESPATCH-TUBE SYSTEM. Albert W. Pearsall, New York, N. Y., assignor to the Pearsall Pneumatic Tube and Power Company, same place. Filed Feb. 10, 1900. Serial No. 4,806.

A suction pneumatic-carrier system or tube apparatus, the combination with a terminal having an outwardly-opening valve across its delivery end, of a vacuum or power chamber surrounding said terminal and communicating therwith through diamond-shaped perforations located in the wall of said terminal close to and surrounding said valve.

657,922.—APPARATUS FOR REHEATING COMPRESSED AIR FOR INDUSTRIAL PURPOSES. Thomas A. Edison, Llewellyn Park, N. J. Filed Dec. 12, 1899. Serial No. 740,065.

An apparatus for heating air, comprising a pipe supplying compressed air from a source of supply to a translating device, a reheater in said pipe for heating the air therein by radiation, a solid combustible in the reheater, a by-pass including the reheater for permitting a portion of the air to pass through the reheater to support combustion and to be heated directly, and means to permit a drop in the air-pressure between the inlet to said by-pass and the translating device to automatically cause



air to flow through the by-pass in quantity depending upon the consumption at the translating device.

658,102. — PNEUMATIC-DESPATCH SYSTEM. Charles S. Bavier and James R. Hawkes, New York, N. Y. Filed Oct. 10, 1899. Serial No. 733,124.

A vacuo despatch system characterized by the combination of a line of tubing, an exhauster operatively connected therewith, and a terminal air-inlet having a closure which automatically shuts the air-inlet when no carrier is being despatched and automatically opens same when a carrier is being despatched.

658,103. — PNEUMATIC-DESPATCH SYSTEM. Charles S. Bavier and James R. Hawkes, New York, N. Y. Filed Feb. 26, 1900. Serial No. 6,483.

The combination in a pneumatic-despatch system, of a pneumatic-despatch tube provided with inlets and outlets for carriers, means operatively connected with said tube and adapted to be actuated by the varying pressure in said tube, a device for exhausting air from said pneumatic-despatch tube, and a governor for said device operatively connected with said means.

658,265.—PNEUMATIC PROPELLING AND STEERING DEVICE FOR SHIPS. Constantin Janczarski, Hughesovka, Russia. Filed Feb. 24, 1900. Serial No. 6,390.

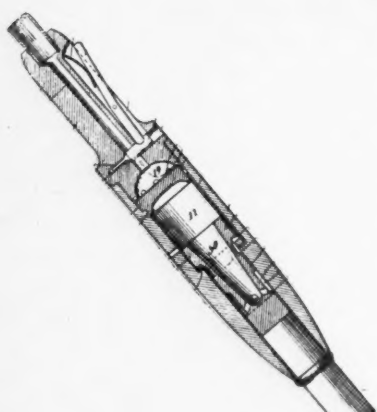
A boat, the combination with the hull, of troughs provided on the under side thereof and adapted to slant upward from the centre to the bow and stern respectively, ports in the bottom of said hull adjacent to the sides of and communicating with said troughs and on either side of the centre of said hull, pipes leading to said ports, a three-way cock governing the air-supply to said pipes, and an air-injector adapted to supply air under pressure thereto.

658,322.—AIR COMPRESSOR AND COOLER. Oscar P. Ostergren, New York, N. Y. Filed March 23, 1900. Serial No. 9,880.

An air-compressor, of an aqueous-vapor separator consisting of the upright hollow cylinder receiving the compressed air at the top and containing injector devices consisting of the two series of funnels, the funnels of one series having the nozzles coacting with each other for injecting effects and being arranged for free upward passage of the air around them and the funnels of the other series adapted to cause the upflowing air to converge over the upper ends of the funnels having the nozzles, to favor separation of the aqueous vapor, the respective funnels of each series being placed intermediately of the funnels of the other series.

658,542.—PNEUMATIC HAMMER. Edmond A. Fordyce, Chicago, Ill. Filed June 3, 1898. Serial No. 682,424.

A valveless pneumatic hammer comprising a cylinder having a bore of large diameter at its upper end and of small diameter at its lower end, each section of said bore being of equal diameter throughout, and a piston having an enlarged head and reduced body to fit said bore, the cylinder having an inlet-port opening into the reduced portion slightly below its top



and an outlet-port opening from the enlarged portion above the normal downward position of the piston, and the piston having an external groove or port slightly below its shoulder, a second external groove or port below said first-mentioned groove or port, and a passage extending from the upper end of the piston to said lower groove or port, the lower end of the cylinder being closed by the piston throughout its range of movement.

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PARIS OFFICES, Aug. 31st, 1900.

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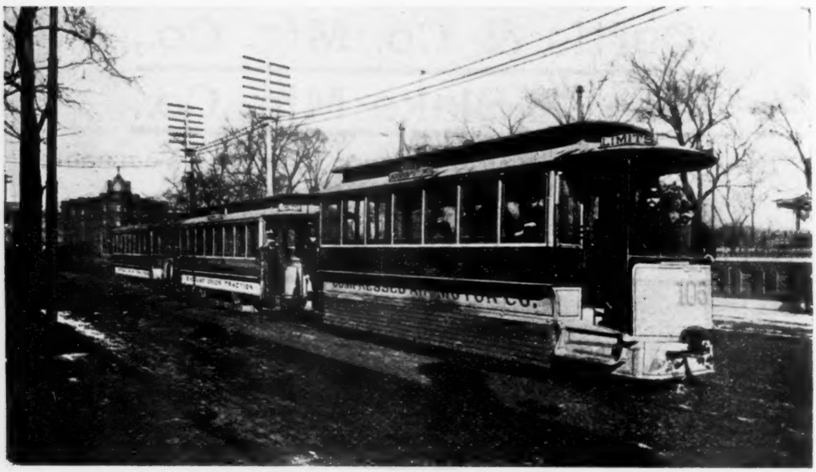

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	1898 (horse)	1899 (air)
Number of cars employed, ...	16	15
Car mileage per day, ...	1310	1530
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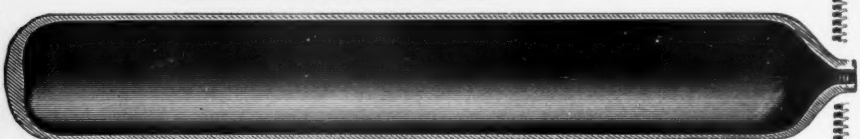

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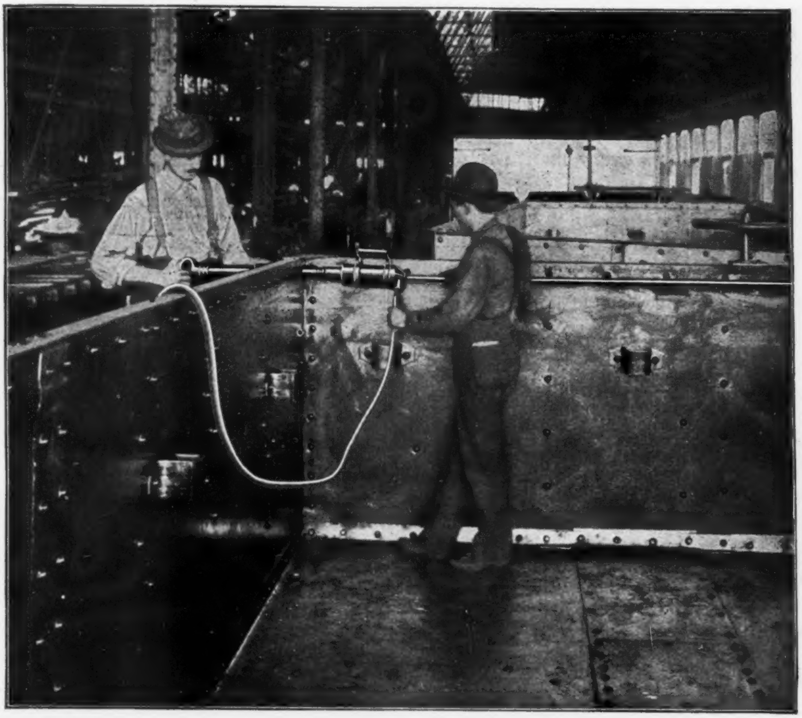

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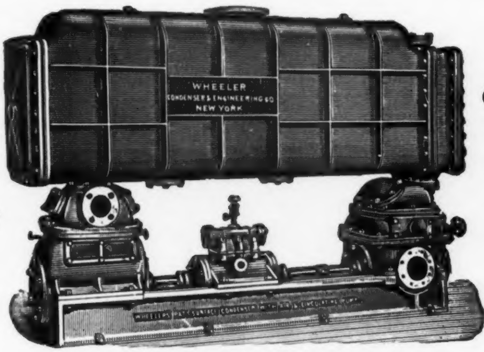

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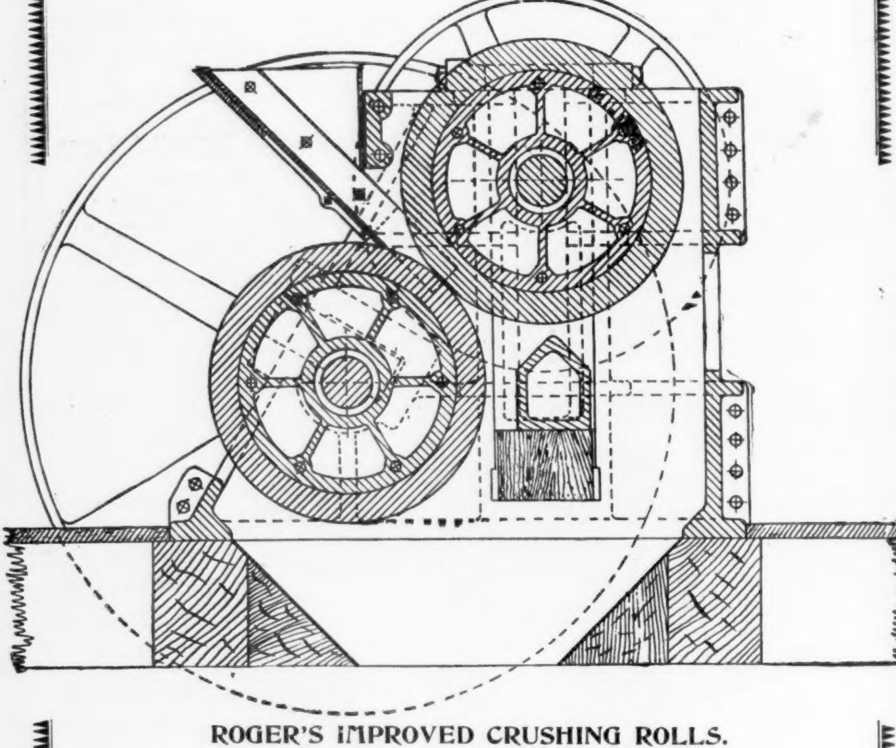

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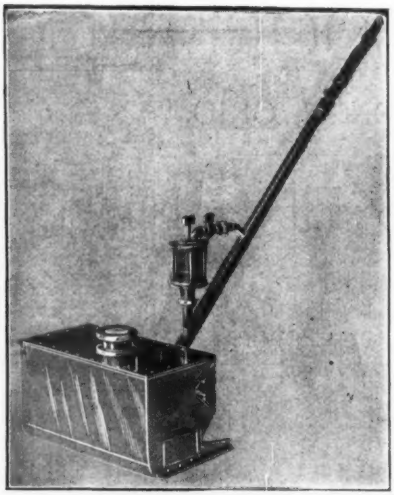

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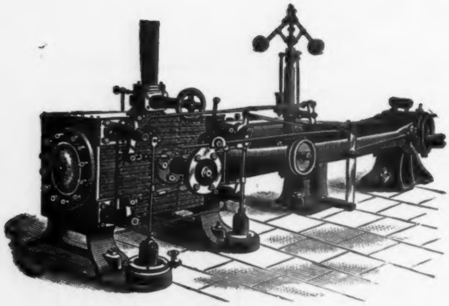

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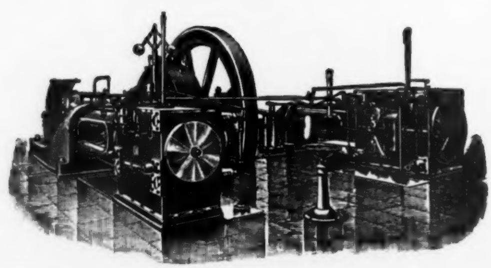

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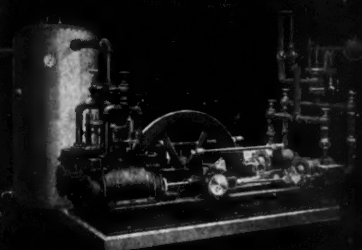

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